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iWHAM- INTEGRATED WATER, HEALTH AND AGRICULTURE MANAGEMENT: PUBLIC HEALTH IMPLICATIONS OF INTEGRATED WATERSHED MANAGEMENT IN A TRIBAL AREA

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Cover photo shows a famous ‘Warli’ painting from the study area, i.e. Jawhar. The painting depicts the culture of tribal people living in hilly areas of Jawhar. This is a photograph taken from a building of a school named ‘Divya Vidyalaya’ Jawhar, with permission from the school authorities.

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iWHAM- Integrated water, health and agriculture management: Public health implications of integrated watershed management in a tribal area

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ABSTRACT

Background: Water scarcity remains a major hurdle in the overall development of tribal people living on hilly terrain, and it is one of the major reasons for their various health problems. Integrated watershed management (IWM) aims to increase water availability and to enhance socio-economic development in such areas. There is a lack of information on the implications of IWM on various aspects of public health, especially in hilly tribal areas.

Aim: The overall aim of this thesis was to explore the public health implications of integrated watershed management in a hilly tribal area in India.

Methods: This study was conducted in six tribal villages of Maharashtra, India. In Paper I, six focus group discussions (FGDs) were conducted with men and women from tribal community, who lived in three different villages with different levels of implementation of the integrated watershed management programme (IWMP). Paper II was a cross-sectional survey involving face-to-face interviews with heads of households in the six study villages. There were 142 households from three integrated watershed management villages (IWMV) and 144 households from three non-watershed management villages (NWMV) participated in study. Paper III was a one year prospective study that investigated physico-chemical and faecal coliform contamination of seven water sources (wells) from six villages. Antibiotic resistance of *Escherichia coli* isolated from the water sources was investigated. The incidence of diarrhoea was recorded at regular intervals. For Paper IV, 17 individual interviews and four FGDs were conducted with professional stakeholders involved in rural healthcare and development administration in the same tribal area.

Findings: Tribal people living in hilly terrain perceived that water scarcity was the main reason for their health problems, and that implementation of IWMP was helpful in improving their health and also empowering their families by improving their socio-economic status through development of agriculture (Paper I). The questionnaire-based cross sectional study revealed positive influence of IWM on many aspects of public health including shorter periods of water scarcity (OR=0.02, 95% Confidence Interval (CI) 0.01-0.04), increased use of toilets (OR=6.95, 95% CI 4.07-11.85), increased cultivation of fruit and vegetables (OR=2.61, 95% CI 1.60-4.27), reduction in migration (OR=0.59, 95% CI 0.36-0.97), increased utilization of healthcare facilities and reduced faecal coliform contamination of household drinking water (42% vs 88%) (Paper II). The odds of coliform contamination in water at community sources was 2.3 times lower in IWMV (95% CI 0.81-6.45, p=0.08). The number of severe diarrhoeal cases (18/663 vs. 42/639, p=0.001) was lower in IWMV compared to NWMV. *E. coli* isolates from water sources in NWMV were resistant to a wider range of antibiotics (Paper III). The professional stakeholders in rural healthcare and development administration perceived that integrated watershed management positively influences complex interlinked factors related to the health of tribal people (Paper IV).

Conclusions: This study suggests that in a hilly tribal setting, implementation of IWMP helps in efficient use and management of water for households, as well as for agriculture purposes, and contributes to enhance socio-economic development and public health. IWM appeared to influence public health through positive modification of complex interlinked factors that include hygiene, sanitation, and healthcare practices, agriculture, migration, education etc. Thus, it appears that an integrated water, health and agriculture management (iWHAM) approach will be useful in improving public health in hilly tribal areas with water scarcity.

Key words: agriculture, antibiotic resistance, empowerment of families, integrated watershed management, public health, perceptions, tribal areas, water scarcity.

LIST OF SCIENTIFIC PAPERS

I. **Nerkar SS**, Tamhankar AJ, Johansson E, Stålsby Lundborg C. (2013). Improvement in health and empowerment of families as a result of watershed management in a tribal area in India - a qualitative study. *BMC Int Health Hum Rights*, *13*:42

II. **Nerkar SS**, Pathak A, Stålsby Lundborg C and Tamhankar AJ. Can integrated watershed management contribute to improve public health? A cross-sectional study from hilly tribal villages in India.(Submitted)

III. **Nerkar SS**, Tamhankar AJ, Khedkar SU, Stålsby Lundborg C. (2014). Quality of water and antibiotic resistance of *Escherichia coli* from water sources of hilly tribal villages with and without integrated watershed management - a one year prospective study. *Int J Environ Res Public Health 11*: 6156-6170.

IV. **Nerkar SS**, Tamhankar AJ, Johansson E, Stålsby Lundborg C. Impact of integrated watershed management on complex interlinked factors influencing public health- Perceptions of professional stakeholders from a hilly tribal area of India. (Manuscript)

The papers will be referred to in the text by their Roman numerals I-IV.

LIST OF RELATED PUBLICATION

1. Tamhankar AJ, Diwan V, Sahoo KC, Nerkar SS, Stålsby Lundborg C. (2014). Antibiotics and Antibiotic Resistance in the Aquatic Environment of India. In 'Antimicrobial Resistance: A cause for global concern'. R. Lawrence, Ebrnrzer, J. and Thomas G. (Eds.), *Narosa Publishing house, New Delhi*. 343-348.

2. Sahoo KC, Sahoo S, Nerkar SS, Stålsby Lundborg C, Tamhankar AJ. (2014). Prevalence of antibiotic resistance in *E. coli* in the community and environment of tribals of Malkangiri district of Orissa. In 'Antimicrobial Resistance: A cause for global concern'. R. Lawrence, Ebrnrzer, J. and Thomas G. (Eds.), *Narosa Publishing house, New Delhi.* 349-354.

3. NCBI Submission:
   Nerkar SS, Tamhankar AJ, Khadke P, Akolkar DB., Apurva SR, Deshpande UD, Khedkar SU, Stålsby Lundborg C. (2015). Draft Genome of Enterotoxigenic *Escherichia coli* O139 H28 Strain E24377A obtained from a tribal drinking water source from India. Available: http://www.ncbi.nlm.nih.gov/nuccore/JXRF00000000
   Date of Submission: 24 January 2015.

CONTENTS

LIST OF ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
AES	Advanced Expert System
APHA	American Public Health Association
ASHA	Accredited Social Health Activist
AST	Antibiotic Susceptibility Testing
AYUSH	Ayurveda, Yoga & Naturopathy, Unani, Siddha and Homeopathy
BAIF	Bharati Agro Industries Federation
BAMS	Bachelor in Ayurveda, Medicine and Surgery
CA	Comprehensive Assessment of Water Management in Agriculture
CI	Confidence Interval
CLSI	Clinical and Laboratory Standards Institute
DDD	Defined Daily Dose(s)
ESBL	Extended Spectrum Beta-Lactamase
FGD	Focus Group Discussion(s)
GOI	Government of India
HIV	Human Immunodeficiency Virus
IWM	Integrated Watershed Management
IWMP	Integrated Watershed Management Programme
IWMV	Integrated Watershed Management Village(s)
NGO	Non-Governmental Organization
NWMV	Non-Watershed Management Village(s)
MBBS	Bachelor in Medicine and Bachelor in Surgery
MDGs	Millennium Development Goals
MDR	Multi-drug Resistant
MPN	Most Probable Number
OR	Odds Ratio
PHC	Primary Health Center
UN	United Nations
WHO	World Health Organization

DEFINITIONS

Antibiotic Resistance: The ability of certain strains of bacteria to develop a tolerance to specific antibiotics to which they once were susceptible.

Diarrhoea: The passage of three or more loose or liquid stools per day.

Household or family: A group of persons who commonly live together and would take their meals from a common kitchen.

Integrated watershed management: Integrated watershed management is a process of formulating and integrating a course of actions involving natural and human resources in a watershed, taking into account the social, political, economic and institutional factors operating within the watershed and surrounding river basin and other relevant regions, to achieve specific social objectives.

Migration: Migration was defined as the process of 'moving of people' in response to availability of employment as a laborer or in response to climate conditions.

Professional stakeholder(s): The stakeholders working in the field of rural healthcare and development administration in the study area. Sometimes it is only mentioned as stakeholder(s).

Watershed: The rainfall catchment area that drains to a common point.

Water scarcity: For the purpose of study, water scarcity was defined as perceived lack of water for daily needs.

Tribes: Tribes (Scheduled Tribes) in India refer to indigenous people whose status is acknowledged in the formal national legislation.

PREFACE

Being a student of agricultural sciences, I got several opportunities to serve the rural parts of India. After getting my master's degree in 2001, I worked in the tribal area of the Nandurbar district of Maharashtra. I grew up in a rural setting, being from a farmer's family, and had experienced the hard life in rural areas. Still I was very disturbed by the extraordinary harsh life experienced by the tribal people in the Nandurbar district due to water scarcity and their dismal health conditions. After that, I was exposed to various rural regions of India through my postings while working in various schemes and projects, but in a corner of my mind there always remained my Nandurbar memories of the tribal people. Meanwhile, in 2005, I visited a non-tribal village, Hiware bazaar in Maharashtra, which is an ideal example of how integrated watershed management can benefit rural people. A sentence from a villager, during the Hiware bazaar visit, was etched onto my mind and remained with me all the time thereafter. This sentence was about physicians working in that village.

In 2006, Dr. Tamhankar, invited me to join in his research on antibiotic resistance management, based on my experience in working on pesticide resistance management, and thus I entered the research area of public health. This work brought me in contact with Prof. Cecilia Stålsby Lundborg, our research collaborator, and in due course I came to know about the opportunity of doctoral scholarship through Erasmus Mundus External Cooperation Window, lot 13. The area of public health research had begun to excite me by then. My extensive experience in rural areas, my witnessing of the hardships of tribal people from Nandurbar due to the water scarce situation, and their dismal health, aroused questions in my mind. The sentence of the villager from Hiware bazar formed my research question for the doctoral study i.e. what are the implications of the integrated watershed management for the public health of tribal people? Can integrated watershed management positively influence public health of tribal people? Fortunately I succeeded in getting the Erasmus Mundus scholarship and the journey of my doctoral studies began in 2010.

It was a challenge for me to pursue a doctoral study in public health sciences, as my background was of agricultural sciences. According to my friends, I was in a different track earlier. But I wanted to find out the answer to my question. So I chose a tribal setting for the study. I was well aware that this will not be an easy task. But I continued all the same. The fact that both myself and Prof. Tamhankar had training in water conservation practices and experience in working in rural India made matters a little easier. Furthermore, Mr. Bharat Kakade of BAIF development research foundation, my mentor and an expert in integrated watershed management in tribal areas, offered critical advice. While working with tribal people, I realized many of the problems faced by them. Some of them were known to me and many were new additions to my knowledge. This thesis may not describe everything that is there, the rest remains to be explored. During this exploration, I gained new knowledge and developed many skills. During my thesis work I faced several problems related to microbiology and antibiotic susceptibility tests, because of an absence of good support near my place of work. So I developed skills in microbiology and started my own laboratory unit. After finishing the data collection for my thesis, my wife, who was helping me earlier in my work, has taken over the laboratory and spun it off as an independent small unit giving services locally.

During the thesis work I also discovered that there is space for a good NGO to do work in the subject matter of my thesis. With encouragement from Dr. Tamhankar, we started the work by forming an NGO named "Shashwat Foundation" involving some like-minded people. This will help us to work further for sustainable development in rural and tribal areas of India. I don't know how successful I will be in life, but I want to make my life meaningful by a substantial contribution in the service of society.

1 BACKGROUND

1.1 WATER AND WATER MANAGEMENT

1.1.1 Water

Water is essential for life. Water is important for all plants, animals and human beings to survive. However the quantity of water required by different living things varies. Water is a basic human need and access to minimum quantities of safe water (20 liters per person per day) should be everyone's right (Howard and Bartram 2003). Lack of access to safe drinking water, sanitation and irrigation is directly related to poverty and poor health. For example, in South Asia, a poorer region of the world, 300 million people have no safe drinking water and 920 million people do not have adequate sanitation (Rahaman and Varis 2005). Moreover, we all need water to produce food. Only 2-5 liters of water is required per person per day for drinking, and it is estimated that the total water needed to produce enough food to satisfy a person's daily dietary requirements is approximately 3,000 liters converted from liquid to vapour (CA 2007).

While water is a key driver of economic and social development, it also has the basic function of maintaining the integrity of the natural environment (UN Water 2014). Efficient use of water determines the ability of any country to sustain its economic growth (Pearce 1993). Apart from that, in many countries such as India, Bangladesh and other countries in south Asia, water is a common symbol of humanity, social equity and justice. Water is one of our fascinating links with nature, with the sacred and cultural heritage (Johnston 2012).

The demand for this limited resource is increasing with the world's growing population. Drivers such as demographic and climatic changes increase the stress on water resources. In these situations, proper management of water is necessary. The traditional fragmented approach is no longer viable and a more holistic approach to water management is essential.

1.1.2 Integrated Water Resources Management (IWRM)

"Integrated water resources management is a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Hassing 2009).

The rationale behind the IWRM approach is the way forward for efficient, equitable and sustainable development and management of the world's limited water resources and for coping with conflicting demands (UN Water 2014).

There is a great variation in the availability of water in different regions of the world. This happens because of variability of supply through time as a result of seasonal variation or inter-annual variation. In addition there is no predictability in the magnitude of variability and the timing and duration of periods of high and low supply. The variability in water availability has been overcome in several countries by creating supply-side infrastructure to

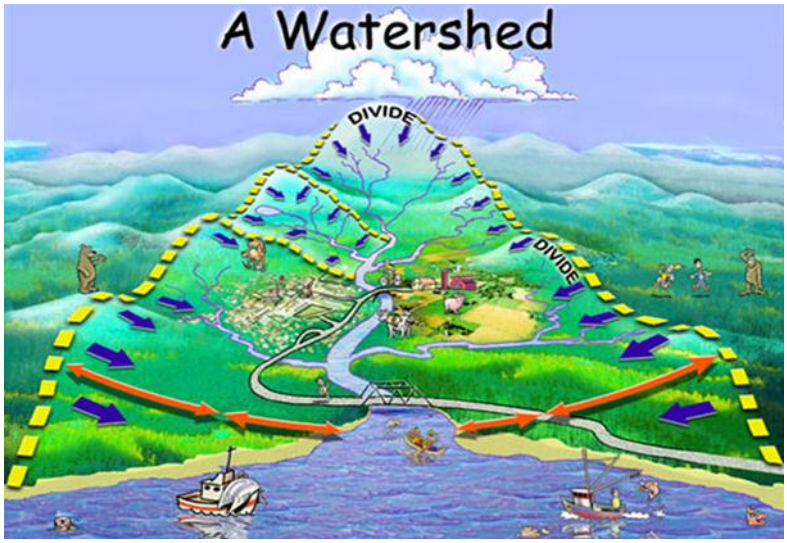
ensure reliable supply and reduce risks. This has many times resulted in negative impact on environment, human health and livelihood. To address the issue of the ever increasing demands from demographic, economic and climatic pressures, waste-water treatment, water recycling and demand management measures are being introduced to counter the challenges of inadequate supply. Loss of water quality due to pollution of water sources is posing major problems for water users as well as for maintaining natural ecosystems (UN Water 2014).

In addition, there are factors like climate change, extreme weather events and changing levels of precipitation that influence the supply of water. The consumption and demand pattern is also changing due to urbanization and agricultural and industrial expansion. As a result some regions are now in a perpetual state of demand outstripping supply and in many more regions that is the case at critical times of the year or in years of low water availability (UN Water 2014). The world's water resources are limited and with an IWRM approach efficient, equitable and sustainable development and management of these resources can be achieved (UN Water 2014).

1.2 IMPORTANCE OF WATERSHED MANAGEMENT

1.2.1 What is a watershed?

A watershed has been defined as: the catchment area that drains to a common point (Kerr 2007); a hydrological unit encompassing lands covering agriculture, forest and other areas, starting from the highest point of an area to the drainage outlet of that area (Sharma 2000). Thus, it is an area from which rainfall water gets collected and is drained to a common outlet like a river or another body of water.



(Source: http://www.recycleworks.org/kids/watershed.html)

Fig 1.1 Illustration showing a watershed

The different phases of hydrological cycles (such as precipitation, surface runoff, infiltration, percolation, evaporation, etc.) in a watershed are affected by human activities. Therefore, watershed is not simply a hydrological unit. It is a socio-political-ecological entity which

plays a crucial role in determining food, social and economic security that provides life support services to people in the catchment area (Wani, Sreedevi et al. 2008).

Watersheds can be of all shapes and sizes depending on their geographical location. The topography of an area determines the size of the watershed. The size of a watershed may range from a few hectares to several thousand hectares. Watersheds can be classified at various levels and depending upon their sizes, they are usually classified into macro, mini and micro watersheds (Shah 2001). These sizes are, of course, relative, and also tentative (Sharma 2000).

A macro watershed covers a larger area and is a combination of many mini and/or micro watersheds. The literature suggests that for the purpose of watershed development, a micro-watershed refers to a small area that generally covers the size of a village and macro-watershed refers to a much larger area (Kerr 2007). The area of a mini watershed would lie somewhere in between the two. This scale of a watershed may refer to a geographical area in number of hectares or may refer to the number of people living in it from a socio-economic perspective (Kerr 2007). When intensive agriculture development is planned in a watershed management programme, the preferred size of a watershed is relatively small.

1.2.2 Watershed management

Conventional watershed management refers to programmes that mainly focus on the management of land and water resources aimed at soil and water conservation in the target area (Matondo 2002). However, the objectives may differ based on the perceived problems of natural resource management in a given area. In high income countries like the United States, Canada or Sweden, the main objective may be to protect water quality in reservoirs. In low and middle income countries like India and countries in the African continent in arid and semi-arid tropics, the main focus is water conservation in rainy season to minimize the problems of water scarcity in other seasons.

1.2.3 Integrated watershed management

Integrated watershed management is a process of formulating and integrating a course of actions involving natural and human resources in a watershed, taking into account the social, political, economic and institutional factors operating within the watershed and surrounding river basin and other relevant regions, to achieve specific social objectives (Dixon and Easter 1986). It is the integrated management of land, water and biomass resources within a watershed (Jain 2004). An integrated watershed management programme with community participation and collective action is more effective in terms of enhanced economic, social and environmental gains (Hinchcliffe, Guijt et al. 1995, German, Mansoor et al. 2007). Integrated watershed management has been implemented with different approaches in India and other countries including USA, Canada, Australia and countries from the African continent (Margerum 2011).

1.2.4 Evolution of integrated watershed management (IWM) in Maharashtra and India

In general, watershed management for ecological reasons, such as reduction of siltation in reservoirs, has been in vogue in India for a long time. By keeping in mind the various ecological benefits, the Government of India invested heavily in macro watershed projects that began in the early 1970s and 1980s with a highly technocratic approach. This approach failed to recognize the need to address the challenges of institutional arrangements for management of these watershed projects. There was also no link to sustainable development. During the 1990s, drawing on past experiences, watershed projects had taken a more participatory approach that focused more on social organization. The area of implementation still remained on the macro-watershed level, and success still remained difficult to see. Meanwhile during the 1980s, some NGOs started watershed development work with much more focus on involving social organizations, and mostly confined themselves to the micro-watershed level, that generated few success stories. Then, watershed management became the focal point of rural development in the country (Farrington, Turton et al. 1999). In 1994, the Government of India formulated guidelines for watershed projects that were primarily focused on management at village level or at a micro-watershed level (GOI 1994). There were some projects in the state of Maharashtra that had collaboration between the Government and NGOs. Adarsh Gaon Yojana (ideal village development scheme), an integrated approach with participation of people, taken up by Mr. Anna Hazare (one of India's best known social activists), proved most successful at Ralegan siddhi site in Maharashtra (Kerr 2002). BAIF development research foundation was another NGO, amongst many others, which implemented integrated watershed management projects with a participatory approach in the tribal area of Maharashtra. The evaluation of many Indian watershed projects suggested better performance and greater success when a participatory approach was used, compared to when only a technocratic approach was used (Joshi 2005).

The more successful projects were found to be implemented in small micro-watersheds and these projects achieved success in terms of reduced soil erosion, increased irrigation, higher crop income, employment generation and improved livelihood (Kerr 2002). In India, besides Maharashtra, there were success stories of effective integrated watershed management from other states like Andhra Pradesh, Karnataka, Rajasthan, Madhya Pradesh and also from some other regions.

This thesis is about integrated watershed management in hilly tribal villages that come under semi-arid tropics of India, where water scarcity is the major issue and in particular about small micro-watershed based projects that actively involve participation of the local people and institutions.

1.3 TRIBAL PEOPLE IN INDIA

1.3.1 What is a tribe?

In general, the term 'tribe' or 'tribal people' refers to a group of indigenous people that have certain characteristics in common that separate them from other populations. A tribe is

defined as a social division in a traditional society consisting of families or communities that is linked by social, economic, religious, or blood ties, with a common culture and dialect, typically having a recognized leader (Oxford). In anthropology, it is defined as a smaller population which has temporary or permanent political integration, defined by traditions of common descent, language, culture, and ideology. Anthropologists prefer to use the term 'ethnic groups' than tribes and define it as a group of people with a common ancestry and language, a shared cultural and historical tradition, and an identifiable territory (Britanica).

1.3.2 Tribes in Indian context

In an Indian context, a tribe is a group which possesses certain qualities and characteristics that make it a unique cultural, social, and political entity. The nature of Indian tribes has changed considerably over time, but certain characteristics have remained the same (India Tribes). Currently, tribes (scheduled tribes) refer to indigenous people whose status is acknowledged in the formal national legislation. The constitution of Indian republic, in its article 342, recognizes a list of so called 'Scheduled Tribes' in India. The essential characteristics for a community to be identified as Scheduled Tribe (GOI 2013) are –

a) Indications of primitive traits;
b) Distinctive culture;
c) Shyness of contact with the community at large;
d) Geographical isolation; and
e) Backwardness.

Tribes in India are referred to as 'Adivasi' or 'Upjati' in India`s national language 'Hindi'. Some of these characteristics may or may not exist in all tribal communities in India. The tribal population of India is 104 million, which constitutes about 8.6% of the total population. About 90% of them live in rural areas and 10% in urban areas (Chandramauli 2011).

1.3.3 Economy and education of tribal people

Most of the tribal people reside in remote areas such as hilly and/or forest areas and their economy is dependent on agriculture and/or forest produce. They are farmers with small land holdings and their agriculture is dependent on monsoon rain. The literacy rate of the tribal population in India is about 59% compared to the national average of 73% (GOI 2013). Literacy is defined by the Government of India as ability of an individual to read and write with understanding in any language. However, the level of reading and writing has not been defined. The education policy of the government of India entitles all tribal children, between the ages of 6-14 years, to free education. However, the percentage of drop-outs from school is high both among boys and girls in tribal areas. If 100 tribal children enter in class-1, only 29 children complete their education up to class-10 (GOI, Statistics of school education, 2010-11).

1.3.4 Health problems and healthcare system in tribal areas

According to National Family and Health Survey 2005-06 data, in general, among tribal women, the median age at first marriage is about 16 years, which is less than the legally allowed age of 18 years. Both tribal men and women are found to be highly anemic compared to other populations; about 68% of women and 40% of men who had their haemaglobin tested were found to be anemic. Tribal children have the poorest nutritional status and malnutrition is common. About 77% of children are anemic. The percentage of institutional

Table 1.1 Information about basic facilities available to the general population and tribal population in India

Sr. No.	Facilities		General population (%)	Tribal population (%)
1	Drinking water facility	Within premises	53	20
		Near premises	33	46
		Away	15	34
2	Main source of drinking water[#]	Tap	47	24
		Well	10	21
		Hand pump/borewell	40	47
		Other	3	8
3	Bathing facilities	Bathroom/Enclosure with roof[π]	65	31
		No bathing facility (in open)	35	69
4	Toilet (latrine) Facilities	Toilet	42	15
		Pit toilet	11	8
		No toilet	47	77
5	Fuel used for Cooking	Firewood/charcoal	44	78
		Crop residue/cow-dung	16	9
		Kerosene/Gas[$]/other	40	13

[#]Usually the drinking water sources are common for the community in tribal areas; [π]In the case of a tribal population this could be made of locally available material; [$]Gas-Liquified petroleum gas or Compressed natural gas *(Source: Census of India 2011)*

deliveries is about 18% in tribal populations. Water borne infectious diseases are a common occurrence. The under-five mortality rate among tribal population is 95 compared to the national figure of 74 (GOI, 2005-06).

In spite of the efforts of the Government of India, tribal areas continue to suffer from poor maternal and child health and ineffective coverage under national health and nutrition programmes. The healthcare infrastructure in remote hilly tribal areas has been developed as a three tier system and is based on the population norms. The Sub-center of the Primary Health Centre is the most peripheral and first contact point of the primary health care system with the community, which is supposed to serve a population of 3,000. The head of the sub-center is an Auxiliary Nurse Midwife. Sub-centers are assigned tasks relating to

interpersonal communication in order to bring about behavioral change and provide services in relation to maternal and child health, family welfare, nutrition, immunization, control of diarrhoea and communicable diseases. Primary Health Centers (PHC), which serve a population of about 20,000, are the first contact point between the village community and a qualified medical officer, who has a degree of either MBBS (Bachelor of Medicine and Bachelor of Surgery) or BAMS (Bachelor of Ayurveda, Medicine and Surgery). The PHC performs curative, preventive and promotional activities, and Family Welfare Services. Community Health Centers are established and maintained by the State Governments and are expected to serve a population of about 80,000 in a tribal area (GOI 2013).

1.4 WATER SITUATION GLOBALLY AND IN TRIBAL AREAS OF INDIA

1.4.1 Global water scarcity

According to Molden et al., one-fifth of the world population, more than 1.2 billion, lives in areas of physical water scarcity. About 1.6 billion people live in water scarce basins, where human capacity or financial resources are insufficient to develop adequate water resources (CA 2007). In many places, competition for scarce water resources is intense. With the growing population, the problem of water scarcity is likely to increase and gain in complexity in the near future (Rijsberman 2006). Water scarce situations have become the reason for internal conflicts within some countries and also international conflicts between countries (Swain 2004). The situation of water scarcity is a growing concern, but the main reasons for this water problem lie in lack of commitment to water and poverty in terms of inadequately targeted investment, insufficient human capacity, ineffective institutions, and poor governance (CA 2007).

1.4.2 Water scarcity and health

Water scarcity can impact the health of the people by reducing water available for hygiene and sanitation. According to estimates, globally, 1.1 billion people lack access to safe drinking water and 2.6 billion lack improved sanitation (Moe and Rheingans 2006). Lack of proper hygiene and sanitation leads various infectious diseases (Prüss, Kay et al. 2002). Water scarcity also affects human health by affecting the diet (Cairncross and Cuff 1987). Access to water is difficult for millions of poor women and men (Viala 2008). In dry arid parts of the world, women have to spend significant productive time and effort to collect water for daily needs (Sullivan 2002).

1.4.3 Water for agriculture

In the last 50 years, the world's population grew by more than 2.5 times, from 2.5 billion to 6.5 billion, the irrigated area doubled, and water withdrawals tripled (CA 2007). Groundwater is the major source of water, for domestic as well as for agriculture use, in many parts of the world including India. It is depleting at a faster rate than its replenishment, leading to a water crisis in many regions and has become a cause of socio-economic stress (Rodell, Velicogna et al. 2009). Greater use of water for agriculture benefits farmers and poor people, propelling

economies, improving livelihood and fighting hunger (CA 2007). Rain-fed agriculture still covers a large area and will continue to play a dominant role in providing food and livelihood to increasing populations, especially in arid and semiarid parts of the world (Rockström, Karlberg et al. 2010). Most of the arid regions of the world often suffer water scarcity. Scarcity of water for agriculture reduces crop diversity and agricultural output, thus reducing agricultural income, which in turn leads to secondary health impacts, such as malnutrition and reduced cognitive function in children (Keusch, Fontaine et al. 2006).

1.4.4 Water situation in hilly tribal areas of India

Most of the tribal population in India, as in many parts of the world, lives mainly in forests and/or hilly regions. Groundwater is the main source of water for the majority of the tribal people. Open dug wells are the source of drinking water as well as water for household use. There is often scarcity of water especially in non-rainy seasons of the year. Scarcity of water in major parts of the year leads to improper hygiene and sanitation. Open defaecation is the practice in more than 80% of the rural population (GOI 2013) of India, and scarcity of water is one reason responsible for it. It is also reported to be linked with contamination of drinking water, which further results in epidemics of water borne diseases such as diarrhoea (Bapat, Amudha et al. 2007). The presence of frequent epidemics of water borne diseases in tribal areas suggests faecal contamination of the drinking water in tribal areas, and children are mostly affected (Rao, Yadav et al. 2005). The occupation of most of the tribal people is rain-fed agriculture and water use for irrigation is negligible.

1.4.5 Importance of integrated watershed management in hilly tribal areas of India

According to Raju, et al., 58% of the total food production of the world comes from the 80% of agriculture which is purely dependent on rain (2008). With the growing population, the water resource is becoming scarce especially for food production. The rain-fed areas of the world are those mostly affected by the problem of food insecurity, malnutrition, poverty, ill-health, water scarcity and poor institutional infrastructure (Rockstrom, Hatibu et al. 2007). The integrated watershed management programme, therefore, is considered a solution to these problems by increasing water availability, agricultural production and development of the rain-fed areas (Joshi 2005, Rockstrom, Hatibu et al. 2007).

The management of natural resources through IWMP results in multiple benefits in terms of increasing water availability, increasing food production, improving livelihood, protecting environment and also addressing gender and equity issues. There is a problem of water scarcity for an average of four to five months in the hilly tribal villages of India. This is the situation even after having sufficient rainfall in four months of the rainy season. This clearly suggests the need for management of the water resource in tribal areas. Tribal people living in hilly areas have mostly small land holdings for agriculture, and their farming is dependent on rain. Agriculture is not well developed and lacks innovative skills and technology that suits the local needs. Food production from this subsistence agriculture is low and does not fulfill

the basic requirement for nutrition for the tribal people. In these hilly tribal areas, villages are situated in small micro-watersheds. The benefits of integrated watershed management mentioned in the literature suggest that these benefits are more concretely seen and are actively facilitated in case of small scale micro-watershed projects with a focus on social organizations (Kerr 2007). Therefore integrated watershed management may be helpful in improving the situation related to water availability and development of agriculture in the hilly tribal areas of India. This could potentially have an impact on the public health situation in these tribal areas.

1.5 RATIONALE OF THE STUDY

The definition of health given by WHO, i.e. 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity', suggests that many aspects of a healthy life lie outside the health system. The mental and social well-being part of the health indicates the broader impact of social and environmental components on health. Water scarcity in many parts of the world affects many aspects of public health. Tribal people living in hilly regions are sufferers of water scarcity, which affects their health. Apart from physical health, many social and environmental determinants of health are associated with water scarcity in hilly tribal areas. Integrated watershed management has been seen as a solution to water scarce situations by effective management of water resources within a particular geographical area. It plays a significant role in building resilience in arid areas by improving water availability, increasing food production, improving livelihood, protection of the agro-ecosystem, addressing gender issues and generation of social capital and economic benefits for the rural population (Veale 2010). The literature reviews suggest that the link of IWM with various aspects of health has not been well established and concrete information on public health implications of integrated watershed management is not available (Parkes, Morrison et al. 2008), especially in the context of tribal people. Therefore this study was undertaken in a tribal area to understand the perceptions of tribal villagers with respect to the public health implications of integrated watershed management in their area, further exploring the same in quantitative studies. The perceptions of professional stakeholders in rural healthcare and development administration were also explored.

2 AIMS AND OBJECTIVES

2.1 OVERALL AIM

To explore the public health implications of integrated watershed management in a tribal area in India

2.2 SPECIFIC OBJECTIVES

- To explore the perceptions of a tribal population on public health implications of integrated watershed management. (Paper I)

- To explore knowledge, attitudes and practices of households in tribal villages with and without implementation of the integrated watershed management programme, regarding water, hygiene and sanitation, and health. (Paper II)

- To explore the quality of water, occurrence of bacterial contamination in water, incidence of diarrhoeal cases, antibiotic use in the community and antibiotic resistance of *Escherichia coli* found in the water sources of hilly tribal villages, with and without implementation of integrated watershed management programme. (Paper III)

- To explore perceptions of professional stakeholders of rural healthcare and development administration on public health implications of integrated watershed management in a tribal area. (Paper IV)

3 METHODS

3.1 OVERVIEW OF THE STUDY DESIGN

There are four studies included in this thesis, presented as four papers (I-IV). Paper I was a qualitative study using focus group discussions (FGDs) to explore the perceptions of tribal villagers on public health implications of integrated watershed management. Paper II was a quantitative cross sectional study based on household interviews with a structured questionnaire conducted in the study villages, and a field test of faecal coliform contamination of household's drinking water. Paper III was a prospective study conducted over a period of one year to investigate the physico-chemical and faecal coliform contamination of water sources, antibiotic use in study villages and antibiotic resistance in *Escherichia coli* isolated from water in the study villages. Paper IV was a qualitative study conducted to explore the perceptions of professional stakeholders in rural healthcare and development administration on public health implications of integrated watershed management.

Details of study focus, study type, study participants, data collection methods and data analysis are given in Table 3.1.

3.2 STUDY SETTING

The state of Maharashtra is situated in the western part of India. It is the second most populous and third largest state by geographical area. Scheduled tribes constitute 9.4% of the total population (112,374,333) of Maharashtra State and this is 10% of the total tribal population of India (Chandramauli 2011). There are 35 districts in the state of Maharashtra and nine districts have sizable tribal populations (GOI 2011). This study was conducted in Jawhar administrative block, one out of 15 administrative blocks of Thane district[1]. The Jawhar block experiences three distinctive weather seasons in a year; a rainy season (June to September), a winter season (October to January) and a summer season (February to May). The terrain of Jawhar block is hilly with sparse and patchy forest cover, and is characterized by scarcity of water during a large part of the year. The area receives approximately 2500 mm of rainfall per annum, mainly in rainy season, compared to the national average of approximately 1100 mm (Panigrahy, Kale et al. 2010). Despite receiving adequate rainfall, tribal people face water scarcity in non-rainy seasons. Ninety percent of the population of the Jawhar block constitutes of tribal people (GOI 2011). The non-tribal population is concentrated in Jawhar town, whilst the rural areas mainly have a tribal population. The literacy rate of the Thane district is 84% while the literacy rate of the rural Jawhar block is 45% (GOI 2011). The literacy rate of India's tribal population is 58% (GOI 2011).The main occupation of the majority of tribal people is agriculture, which is not well developed.

[1] Thane district is bifurcated into two districts, Thane and Palghar, by the government of Maharashtra on 1st August 2014. The study area now comes under the newly formed Palghar district. For the purpose of this study (papers I to IV) reference is made to the Thane district, as all data were collected before the bifurcation of Thane district.

Figure 3.1 Map of India showing Maharashtra state and Thane district

Tribal people in this area receive health services from the government, free of charge. These services are provided through ASHA (Accredited Social Health Activist) at village level, through primary health centers for a group of villages and through a community hospital in a town at block level. Traditional healers, called 'Bhagat' are also present. People also seek health services from a few private physicians in towns.

The study was conducted in six villages selected on the basis of the implementation of the Integrated Watershed Management Programme (IWMP). There were three villages in which IWMP was implemented, which hereafter will be referred to as 'integrated watershed management villages (IWMV)' and in the remaining three villages, there were no activities related to IWMP. These villages are hereafter referred to as 'non-watershed management villages (NWMV)'. In the selected study villages, all people belonged to the tribal population.

3.3 DATA COLLECTION

The data of the qualitative studies was collected using focus group discussions (FGDs) and individual interviews. For the quantitative studies, face to face questionnaire based interviews, records from health centers, field tests and laboratory test results were used.

Table 3.1 Summary of study types, data collection methods, study participants and data analysis

Paper/ Study	Focus	Study type	Data collection method and study participants	Period of data collection	Data analysis
I	Perception of villagers	Qualitative study	6 focus group discussions among villagers in 3 villages ➢ 3 with men (1/village) ➢ 3 with women (1/village) ➢ Total participants- 45	April – August 2011	Manifest and latent content analysis
II	Household survey	Quantitative Cross-sectional study	A questionnaire based survey in six study villages ➢ Households in IWMV (142) ➢ Households in NWMV (144) ➢ Households drinking water samples for testing faecal coliform contamination (IWMV=142, NWMV=140) ➢ Data on diarrhoea from each households three times in a year (August 2011, Dec. 2011 and April 2012)	August - 2011 to April-2012	Descriptive statistics and chi-square test
III	Water quality, antibiotic use in the community and antibiotic resistance of *E. coli* in community water source	Quantitative Prospective study	Monthly water testing for quality from 7 water wells (IWMV=4 wells, NWMV=3 wells) for one year ➢ 76 water samples (IWMV=45; NWMV=31) ➢ Coliform count/100 ml of water ➢ Antibiotic Susceptibility of *E. coli,* Collection of data from records of health center	July -2011 to June 2012	Descriptive statistics and chi-square test
IV	Perception of stakeholders	Qualitative study	4 focus group discussions and 17 individual interviews among professional stakeholders ➢ Total participants - 49	November 2013 to March 2014	Manifest and latent content analysis

IWMV—Integrated Watershed Management Villages; NWMV—Non-Watershed Management Villages.

Qualitative studies (Study I, IV)

Study I was conducted in three villages that were selected on the basis of implementation of IWMP. In one village, implementation of IWMP was completed. In the second village, the process of implementation of IWMP had been going on for two years. In the third village there was no activity related to watershed management. For conducting the FGDs, purposive sampling was used to select the individual participants from each village, in order to achieve variation with respect to sex, age and literacy. A total of six FGDs were conducted among the villagers in the three villages. There were two FGDs in each village, one for men and one for women.

For study IV, individual interviews and FGDs were used for data collection. Purposive sampling was used to select the individual participants for the individual interviews as well as for the FGDs. Participants from different levels of the hierarchical ladder were chosen. Participants were selected based on the kind of service and experience of work they had in the tribal area, (preferably having experience in the study area for at least one year). Individual interviews were conducted with stakeholders, for whom grouping of individuals was not possible. These stakeholders were fewer in number and were in higher positions in the administrative hierarchy and were based at block/district/state level. FGDs were conducted with stakeholders working at village level. In total, 17 individual interviews and four FGDs were conducted.

For all FGDs (both for paper I and IV), the author (SSN) was the moderator. For FGDs with women, an additional female moderator was involved. The author conducted all individual interviews. All FGDs and interviews were conducted in the local language 'Marathi'. The moderators, male and female, were well aware of the language and also had a good understanding of tribal customs and traditions in the study area.

Quantitative studies (Study II, III)

Study II

For study II, all households in the six study villages were included. This was a cross-sectional study for which a questionnaire was developed based on information generated in Study I. Consultations were also done with experts in the field of watershed management to understand the influence of watershed management on health in a tribal context. The questionnaire included questions on the following: demographics; water availability; crop patterns and income from agriculture; staple food; hygiene and sanitation; utilization of healthcare services; and knowledge about integrated watershed management. A "yes or no" 10-item questionnaire was also included in this study to quantify the views of the people on how IWMP can influence their health. The questionnaire was pilot tested in 20 households for face validity before the actual study. The data collection was done with the help of study assistants, who belonged to the tribal community, but not the study villages. They were students in the discipline of rural development in a nearby town. The study assistants were

therefore well aware of the local language, traditions and practices that the local community followed. They were further trained during the pilot study to conduct interviews. The head of each household, male or female was interviewed. If the interviewee was unaware of IWMP activities, a short explanation about IWMP was given with an example of a village where IWMP had been implemented. In each village, all the interviews were conducted on the same day to avoid discussion among the villagers about the interview. Along with the interview, drinking water quality was tested at household level using a commercial hydrogen sulfide test kit (Rapid H2S kit-Microexpress, Tulip, India). Manufacturer's specifications were followed and 20 ml of water was collected from the storage container of each household and tested for fecal contamination (Manja, Maurya et al. 1982). For data on diarrhoea, repeated cross-sectional data was collected three times in a year, at an interval of four months by the study assistants. Each household was asked about the occurrence of diarrhoea among household members in the past 15 days.

Operational definitions for study II

For this study, water scarcity was defined as perceived lack of water for daily needs. Water scarcity was considered to be prolonged if it exceeded more than four consecutive months in a year. A physically accessible water source was defined according to the WHO definition as a source that was located within 1000 meters of the household and had a water collection time that did not exceed 30 minutes (WHO 2012). Migration was defined as the process of 'moving of people' in response to availability of employment as a laborer or in response to climate conditions (Human migration guide 2005). Diarrhoea was defined as the passage of three or more loose or liquid stools per day (WHO 2014).

Study III

For study III, all six study villages were included. Open dug community wells were the main source of water in all villages. There were seven water wells in the six study villages and they were all included for water sampling. The four wells of IWMV were labeled- IWMV1 to IWMV4 and three wells of NWMV were labeled- NWMV1 to NWMV3. Two water samples of 250 ml were collected from each well at monthly interval in sterilized glass bottles following standard procedures (CAWST 2009). Immediately after collection, one sample was evaluated using a field level rapid testing kit (WT023, Hi-Media) for eight physico-chemical water quality parameters, namely: pH, turbidity, chlorides, total hardness, nitrates, iron, residual chlorine and fluoride (HiMedia 2014). The second water sample was kept in a thermo-insulated icebox (4^{o}C) and was transferred to the microbiology laboratory for analysis of bacterial contamination.

The Most Probable Number (MPN) method was used to estimate the total coliform count of bacteria in water samples. The multiple tube technique was employed (APHA 1998). Mac-Conkey broth medium was used in 15 test tubes with added inverted Durham tubes for gas collection. The observation on acid and gas production in each row of five tubes was noted and coliform count was recorded using McCrady's table. *E. coli* was differentiated from other

fecal coliforms using selective medium, eosin methylene blue agar followed by Eijkman test (Batty-Smith 1942). Identified *E. coli* isolates were further confirmed by Vitek 2 (bioMerieux, Marcy l'Etoile, France) compact instrumentation (Vazquez 2001). Confirmed *E. coli* isolates were tested for their antibiotic susceptibility by using two cards of Vitek 2 instrument namely AST-GN25 and AST-EXN7 (Appendix V). Both cards covered a total of 34 antibiotics that included: tetracyclines, penicillins, all generation cephalosporins, carbapenems, trimethoprim/sulfamethoxazole and quinolones. Care was taken to include antibiotics that were used in the study area. The data on the occurrence of diarrhoeal cases was collected from the records of PHCs at regular intervals during the study period. Data on antibiotics delivered to sub-centres of primary health centres (PHCs) in the study villages from 2008-2012 was obtained from records. This data was used as a proxy for antibiotics consumed by the population in the study villages, and is presented as Defined Daily Doses (DDDs)/1,000 inhabitants/year. The DDD is a drug's assumed average maintenance dose per day, used for its main indication in adults (WHO 2012a).

3.4 DATA MANAGEMENT AND ANALYSIS

Qualitative studies

For study I, the recorded FGDs were transcribed verbatim in 'Marathi'. These were then translated into English. For study IV, FGDs and interviews were transcribed verbatim in 'Marathi'. Manifest and latent content analysis were used as methods for analysis (Graneheim and Lundman 2004). Analysis was done of the English transcript for study I and of the Marathi transcript for study IV. First, open codes were identified in the text. For study I, both transcripts *viz*. English and Marathi were used while identifying codes to understand the actual meaning of the text. For study IV, open codes and relevant quotations were translated into English at this stage. Codes were grouped into sub-categories according to similar patterns and sub-categories were further grouped to form categories to achieve the manifest level of the content analysis. Finally, one theme, the underlying meaning of the text, was identified.

All the translations were cross-checked by one of the co-authors (AJT), having command of both the languages. The first and second authors (Paper I and IV) have a good understanding and long experience in participating in projects in rural India. All authors have a public health perspective and experience from qualitative research and varied professional backgrounds, namely agriculture, environmental health, nursing and pharmacy.

Quantitative studies

The data was entered in Microsoft Excel, cross-checked and analyzed using Stata 12.0 (Stata Corp., College station, Texas, USA). Descriptive statistics were used to present the data. Pearson's chi square test was used to test statistical significance as applicable.

For study II, the relationship between each variable and the outcome was explored using the odds ratio (OR) estimated with a 95% confidence interval (CI). A P-value of less than 0.05

was considered statistically significant. For study III, the OR estimated with a 95% CI was used to determine the strength of association between IWMP and coliform contamination of water. A P-value of less than 0.05 was considered statistically significant while a P-value between 0.05 and 0.10 was considered as 'borderline significant'.

3.5 ETHICAL APPROVAL

This study was approved by the Institutional Ethics Committee of R. D. Gardi Medical College, Ujjain, India (No.175/2011). Informed oral consent was obtained from all participants of FGDs and individual interviews. Participation was voluntary and the participants were informed that they could withdraw at any time without any implications. Permission was also taken from local authorities concerned, for the collection of water samples and collection of data related to the study. The participants of the study and the local authorities were/will be informed regarding the outcome of the studies.

4 MAIN FINDINGS

The main findings are divided into following two sub-sections.

1. Interrelationship of water and health in the context of IWM.
2. Interrelationship of water, agriculture and health in the context of IWM.

The findings of the included papers (I-IV) are integrated under different sub-headings. Quotes from FGDs and individual interviews for papers I and IV, are presented under each category to illustrate the findings. Within the quotes explanations are given in square brackets.

4.1 INTERRELATIONSHIP BETWEEN WATER AND HEALTH IN THE CONTEXT OF THE INTEGRATED WATERSHED MANAGEMENT

4.1.1 Water Availability

Villagers participating in the FGDs (I) perceived that water scarcity is the major problem in the tribal area in general, and perceived the severity of the water scarcity was different in IWM and NWM villages. Participants from IWM villages perceived that there was an improvement in water availability after implementation of IWMP and that the water scarcity periods had reduced significantly.

> *"After implementation of IWMP, water remains in the well till April. Earlier, it used to become dry in January-February."* (FGD-Men, IWM village)

All the participants perceived that women spent most of their productive time collecting water required for household purposes. Women participants from the NWM villages emphasized that development in their village was not occurring due to scarcity of water. They also had hope for development if they get enough water.

> *"If we have enough water, we will grow vegetable crops. We will grow crops in a better way and we may stay on the farm itself....we should get water near our house....we should get clean [drinking] water."* (FGD-Women, NWM village)

The perceptions of the professional stakeholders (IV) in rural healthcare and development administration (hereafter referred to only as 'professional stakeholders' or 'stakeholders') did not differ from villagers with regards to water scarcity in the tribal villages in the Palghar-Thane district. (In general, unless specifically mentioned as of NWMV, any description mentioned for 'tribal people' applies to tribal people of Thane-Palghar district.) They stated that tribal people have to walk longer distances to fetch water in the scarcity period in the summer. The stakeholders also opined that there is enough rainfall in this hilly tribal area, but in villages where IWMP is not implemented, there is no conservation of water and there is a lack of management of water supply in such villages.

While sharing their experiences on the impact of IWMP on water scarcity, the stakeholders perceived that there was an increase in water availability, and now water sources have become closer to the households in villages where IWMP was implemented.

"Earlier in that village [before IWMP implementation], there was water scarcity. Now there are trees and every nala [stream] has water flowing" (FGD, Local leaders)

In the questionnaire study (II), respondents from all households reported water availability to be less in their village during some part of the year. A significantly lower number of households from IWMV reported having prolonged water scarcity compared to NWMV (20/142 versus 126/144, OR = 0.02, 95% CI 0.01-0.04; $p < 0.001$). A significantly higher number of households from IWMV had a physically accessible water source (less than 1000 meter from house) during a scarcity period compared to NWMV (123/142 versus 103/144, OR = 2.57, 95% CI 1.42-4.66; $p = 0.002$).

4.1.2 Water, sanitation and hygiene

Use of toilets

All the participants from study–I perceived that water scarcity affects sanitation practices as well as personal hygiene. In general, participants were of the view that use of toilets depends on the availability of water. In the NWM village, both men and women FGD participants (I) stated that they do not have toilets as they are not useful for them because of water scarcity, so they follow open air defecation. In comparison, most participants from IWM villages stated that they use toilets.

The professional stakeholders perceived (IV) that hygiene and sanitation practices followed by tribal people were improper, and that water scarcity was one of the reasons for this. Open air defecation was a common practice in the tribal villages of Palghar-Thane district, and professional stakeholders also opined, that water scarcity is one of the major reasons for open air defecation and the subsequent contamination of water in community water wells in the region.

"We say, that every house should build a toilet…but an important problem is, that they [tribal people] do not have water to drink,... so how could they have water for toilet use. That is why they go to open air places [for defecation]." (Teacher, 15 years experience)

[Even for dry toilets, about 1 liter of water is required per person per time in India as it is customary in India to use water for cleaning instead of tissue paper]

However, professional stakeholders perceived (IV) that in IWM villages, the hygiene and sanitation- related situation was better compared to other villages.

"In the integrated watershed management village, cleanliness is there; the water source is located close by, facilitating taking baths and washing of clothes." (FGD, Healthcare provider)

A significantly higher number (122/144, 85%) of households (II) followed open-air defecation in NWMV, compared to IWMV (63/142, 44%) (OR = 6.95, 95% CI 4.07-11.85; *p*

< 0.001). There were significantly higher numbers of toilets in IWMV (83/142, 58%) compared to NWMV (27/144, 19%) (OR = 6.09, 95% CI 3.46-10.83; $p < 0.001$).

Hand washing, bathing and washing of clothes

The professional stakeholders stated (IV) that tribal people neglect hand washing and the questionnaire based study also revealed the same. In the cross-sectional study (II), there were no significant differences in the reported practice of hand washing using soap and water between IWMV and NWMV after defecation (82/142 versus 80/144, OR = 1.09, 95% CI 0.66-1.79; $p = 0.708$) or before meals (42/142 versus 35/144, OR=1.30, 95% CI 0.74-2.28; $p = 0.314$). A significantly higher number (85/142; 60%) of households from IWMV reported taking a bath at home compared to NWMV (59/144, 41%) (OR = 2.14, 95% CI 1.34-3.43; $p = 0.001$). The remaining households in both settings used a river for bathing. A river was also the most common place for washing clothes in both settings i.e. IWMV and NWMV, but a significantly higher number of households in IWMV (53/142; 38%) were having other options like wells, check dams or ponds when compared to NWMV (23/144; 16%) (OR=3.13, 95% CI 1.81-5.42; $p < 0.001$).

4.1.3 Water contamination and water borne diseases

Participants stated (I) that they had to change their source of drinking water in the summer season; for a few days for IWM villages, and for several months in NWM villages, because of insufficient water in the nearest water well. According to participants from all FGDs and especially from NWM villages, if they get assured supply of water from a single source throughout the year, then disinfection of the drinking water source can be done regularly and diarrhoeal diseases can be reduced.

> *"If we get it [water] for 12 months from the same well, then illness [diarrohea] will not be much as water will get disinfected regularly."* (FGD-Men, NWM village)

There were significant differences in the views of villagers (II) in IWMV and NWMV with respect to the need for disinfection of drinking water at the community source. Disinfection of the water source throughout the year was viewed as more important in IWMV compared to NWMV (85% versus 66%). This difference was statistically significant (OR = 2.81, 95% CI 1.60-4.92; $p < 0.001$).

When drinking water from household storage was tested, the faecal coliform contamination of water was found (II) to be significantly higher in NWMV compared to IWMV (88% versus 42%, OR 10.20, 95% CI 5.83-17.85; $p < 0.001$).

Women FGD participants (I) did not consider hygiene at household level as one of the factors for diarrhoeal and other diseases but thought it originated from a community resource.

The data on monthly faecal coliform contamination (III) in each water well, measured as coliform count/100 ml of water, showed that in the case of IWMV, 17 samples out of 45 (38%), were contaminated. This figure was 18 out of 31 (58%) in the case of NWMV. The

odds of water samples having coliform contamination was 2.3 times higher in NWMV compared to IWMV (95% CI 0.81-6.45, p = 0.081). This difference showed borderline significance, and a wide confidence interval indicated that the results were tilted towards IWMV, suggesting a contribution of components of IWMP on the reduction of bacterial contamination of water. The contamination level, measured as coliform count/100 ml, was in the range of 0 to 7900 for IWMV and 0 to 13000 for NWMV.

According to the professional stakeholders (IV), stomach problems and diarrhoeal diseases were very common illnesses in the area. Other observed illnesses included fever, common cold, skin infections, eye infections, hepatitis, pneumonia and malaria. Participants felt that all these illnesses were water-related, resulting from factors such as: improper hygiene practices such as irregular bathing; hand washing negligence; and insufficient care of infants, all for which water scarcity is responsible.

> *"In these villages, diarrhoeal diseases are most prevalent,…….there is contamination of water, lack of hygiene,….fever and cold with stomach problems are other problems"*
> (FGD, Frontline healthcare providers)

The proportion of inhabitants treated (III) for diarrhoea at the PHC sub-centres was significantly lower (p = 0.001) in the IWMV (18/663) compared to the NWMV (42/639).

4.1.4 Antibiotic use in the community and antibiotic resistance in water sources

The total of antibiotics delivered (III) to PHC sub-centers in both types of villages are presented as DDDs per 1,000 inhabitants per year in Table 4.1. The figures were higher in IWMV compared to NWMV during the study period i.e. 2011-2012. This was also true for the previous three years.

The *E. coli* isolated from the community water wells showed high susceptibility to the antibiotics tested (III) in the study villages. In IWMV 65% and in NWMV 61% of *E. coli* isolates were found susceptible to all tested antibiotics (Table 4.2). Amongst the resistant *E. coli* isolates, three isolates from both the settings, i.e. IWMV and NWMV, were resistant to only one group of antibiotics (Table 4.2). Two isolates from NWMV were multi drug resistant (MDR) i.e. resistant to three or more groups of antibiotics, compared to a single MDR isolate in IWMV. One isolate from NWMV produced ESBL (Extended Spectrum Beta-Lactamases).

Table 4.1 Data on the yearly average antibiotics delivered (DDDs/1,000 inhabitants/year) to sub-centers of Primary Health Centre during the years 2008–2011 and 2011–2012 in tribal villages with and without the implementation of the integrated watershed management programme

	2008-11 (June- May)		**2011-12 (June- May)**	
Antibiotics (Assigned DDDs)	**IWMV** DDDs/TIY	**NWMV** DDDs/TIY	**IWMV** DDDs/TIY	**NWMV** DDDs/TIY
Tetracycline, 1 g	458	391	302	39
Ampicillin, 2 g	6	-	-	-
Amoxicillin, 1 g	163	33	38	58
Co-trimoxazole, 2 g	267	225	124	99
Erythromycin, 1 g	-	27	-	-
Ciprofloxacin, 1 g	7	52	-	-
Norfloxacin, 0.8 g	75	47	189	156
Nalidixic Acid, 4 g	-	-	1.5	-
Total	**976**	**775**	**654**	**352**

IWMV—Integrated Watershed Management Villages; NWMV—Non-Watershed Management Villages; DDD—Defined Daily Dose; PHC—Primary Health Center; TIY—Total inhabitants per year.

Table 4.2 Co-resistance and Multi Drug Resistance (MDR) of *Escherichia coli* from well water of tribal villages with and without the implementation of the integrated watershed management programme

	IWMV (N=17)	**NWMV (N=18)**
	n	*n*
Resistant to one group of antibiotic	3	3
Resistant to two groups of antibiotics (Co-resistance)	2	2
Resistant to three or more groups of antibiotics (MDR)	1	2
Susceptible to all	11	11

N—Total number of isolates; IWMV—Integrated Watershed Management Villages; NWMV—Non-Watershed Management Villages.

Resistance to tetracycline and nalidixic acid was the most common in both the settings. Table 4.3 shows that *E. coli* isolates from NWMV exhibited resistance to a wider range of antibiotics. Resistance was recorded to 2nd and 3rd generation cephalosporins, nitrofurantoin and aztreonam in NWMV, which were not delivered in these villages.

Table 4.3 Antibiotic resistance patterns of *Escherichia coli* isolated from water wells in tribal villages with and without the implementation of integrated watershed management programme

Antibiotics	**IWMV (N=17)**	**NWMV (N=18)**
	n	*n*
Tetracycline	3	3
Ampicillin	1	3
Cephalothin (1st)	1	4
Cefuroxime (2nd)	0	1
Cefotaxime (3rd)	0	1
Cefepime (4th)	0	0
Aztreonam	0	1
Meropenam	0	0
Co-trimoxazole	0	2
Amikacin	0	0
Nalidixic acid	4	3
Nitrofurantoin	1	2

IWMV—Integrated Watershed Management Villages; NWMV—Non-Watershed Management Villages; *N*—Total number of isolates; *n*—Resistant isolates; 1st—1st generation cephalosporins; 2nd—2nd generation cephalosporins; 3rd—3rd generation cephalnosporins; 4th—4th generation cephalosporins.

4.1.5 Water and women

Women participants perceived (I) that they along with their daughters, had to bear the responsibility of fetching water and firewood from a long distance, which is hard work and made them tired. They stated that they had to spend most of their time on this type of work, and due to this education became a second priority for their daughters. The women participants perceived that implementation of IWMP helped to reduce this hard work to a certain extent.

> *"We [used to] carry it [firewood] on our head....those who have trees in their village, they do not go now.....All were going [to collect firewood], when trees were small....now trees are grown up, so few are going. We were bringing it from a long distance."* (FGD-Women, IWM village)

A total of 90 households in IWMV and 87 households in NWMV reported (II) having a female child between 5 and 16 years old. A significantly greater number of girls were able to continue their education in IWMV (80/90; 89%) compared to NWMV (63/87; 72%) (OR 3.04, 95% CI 1.28-7.64; $p = 0.005$).

In NWM villages, women participants perceived (I) that they worked harder than men.

> *"Men do not work much. Only women work hard. Whether men can do the work of women? Work on the farm, take care of children and family, maintenance of the house by dung slurry!"* (FGD-Women, NWM village)

Women in IWMV thought that the work done by men and women in their village was equally hard. Male participants from IWMV admired the hard work of women. Male participants from IWMV viewed that women play a major role in the control of water borne diseases by supervising disinfection of water in the well. Women participants also perceived that they do most of the work related to hygiene and sanitation at a household level and emphasized their role.

> *"A Woman does it alone…. Carry it [a pot with water] on head,.... All washing pots, clothes, [working with] farm yard manure, cooking food, etc. are done by women only."* (FGD-Women, IWM village)

The professional stakeholders perceived (IV) that traditionally women and girls have to bear the responsibility of fetching water from the distant sources and water scarcity adversely affects women's health. The heavy workload at home and at the farm, make women suppressed and women do not get enough nutrition, which results in anemia, especially in water scarce areas. One of the participants shared his experience as follows.

> *"We were working in nine [tribal] blocks, organizing health camps…..we observed, that the Hb [hemoglobin level] of women from one particular block was very low….and that the same block faces severe water scarcity."* (Development officer, 10 years experience)

Social activities such as formation of self-help groups by women (I) and their participation in such groups was viewed as a positive development that has taken place due to implementation of IWMP. According to the women, it gave them some kind of empowerment and helped them to improve social health by helping to control antisocial behaviour, like intimate partner violence after heavy alcohol consumption by men.

4.2 INTERRELATIONSHIP BETWEEN WATER, AGRICULTURE AND HEALTH IN THE CONTEXT OF INTEGRATED WATERSHED MANAGEMENT

4.2.1 Agriculture, food and nutrition

Participants from NWM villages stated (I) that their agriculture is dependent on rain and their crops are meant mostly for household consumption and not for sale. They also stated that their narrow spectrum of crops and low productivity results in insufficient amounts of food for their families. Participants from IWM villages perceived that the physical look of a person is an indication of his or her nutritional status, which they felt was better in their village compared to NWM villages.

> *"A person from a neighboring village doesn't look good physically, these much of cheeks [showing by acting] are inside."* (FGD-Men, IWM village)

The professional stakeholders perceived (IV) that tribal people grow food-grain crops in the rainy season mainly for household use. At the same time, vegetable consumption is very low as they do not have water to cultivate crops in non-rainy seasons and also they have no

purchasing capacity. According to them, tribal people get neither enough calories, nor a balanced diet, and malnutrition is a serious health issue in the area.

> *"They eat whatever crop they grow, if the crop doesn't yield then there is nothing for sustenance ….They do not bring [buy] vegetables from outside and also do not grow vegetable crops so they do not eat…..mostly eat wild vegetables, that come in the rainy season in the forest"* (Teacher, 15 years experience)

The percentage of households that cultivated (II) only rain-fed crops like rice (*Oryza sativa*), nagali (*Eleusine spp.*), and bhagar (*Echinochola spp.*) were significantly higher in the NWMV compared to the IWMV (88/136; 65% versus 54/131; 41%). The households that cultivated other crops in non-rainy seasons that require water such as vegetable crops e.g. eggplant (*Solanum melongena)*, green chilly (*Capsicum annum*) and also grew fruit trees e.g. mango (*Mangifera indica*), cashew-nut (*Anacardium occidentale*) along with rain-fed crops in rainy season, were significantly higher in IWMV compared to NWMV (77/131; 59% versus 48/136; 35%). These crops generally require irrigation, for which water is needed. The differences in the cropping patterns i.e. rain-fed crops only or rain-fed crops along with fruits and vegetable crops, were statistically different between IWMV and NWMV (OR = 2.61, 95% CI 1.60-4.27; $p < 0.001$).

There were no significant differences in the sale of food-grain crops (rice, *nagali* and *bhagar*) between IWMV and NWMV (OR = 1.36, 95% CI 0.82-2.25; $p = 0.200$). Rice and *nagali* were reported to be the staple food in all study villages. The proportion of use of fine cereals (rice) as a staple food was significantly higher in IWMV (108/142; 76%) than NWMV (80/144; 61%) (OR= 2.02, 95% CI 1.21-3.36; $p = 0.007$). The households in IWMV reported significantly higher consumption of vegetables (OR = 1.71) and fruit (OR = 1.94) after purchasing compared to NWMV.

4.2.2 Agriculture, economy and migration

The professional stakeholders stated (IV) that economy in the tribal villages of Palghar-Thane district is dependent on agriculture, and that most of the tribal people have farming as their main occupation. They stated that farming is dependent on monsoon rain and in other seasons there is no work in the tribal villages. The stakeholders further perceived that unemployment in non-rainy seasons forced the tribal people to migrate to other places to earn money for their livelihood.

> *"In this area, crops are cultivated only in the rainy season; in the summer season there is a problem even for drinking water, how could farming be possible."* (FGD, Frontline healthcare providers)

The professional stakeholders also perceived (IV) that though agriculture is the main occupation of the tribal people in Palghar-Thane district, it is underdeveloped, and tribal people lacked sufficient knowledge of how to cultivate different crops. However, in the IWM villages, agriculture had relatively prospered compared to NWM villages and villagers in the

IWM villages reported (I) benefits in terms of economic gain. They perceived that IWM was beneficial for agriculture as it retains moisture, which could be used to grow an additional or new crop. This was felt to be empowering through generation of income as well as employment. Participants shared their experience regarding benefits of IWM as follows:

> *"Here our land is on hilly terrain. [Generally] there is scarcity of water.....if we wanted to do something different, there was a problem of water..... There are lots of benefits of integrated watershed management. We can [now] sow beans. Even after the rain stops, [fields at downside retain moisture] we can take the crops."* (FGD-Men, IWM village)

Fruit crop plantations, locally referred to as 'Wadi', meaning 'small orchard of fruit crops', enabled through integrated watershed management, was perceived (I) as a hope for sustainable development in all FGDs. Vegetable production was also perceived as a potential area for increase in income as well as for increasing the nutritional status.

FGD participants from NWM village perceived (I) that poverty and unemployment in the area are the results of rain fed agriculture. They further viewed that unemployment forced them into seasonal migration in search of jobs, such as road or house construction, farm work, etc. They stated that the earnings received through wages after migration was the main source of income to support their families. The need for migration to earn some money for sustenance of their family made them feel powerless.

> *"For money, we have to go somewhere...what can we do if we don't have money. If we are at home, we do not get money. We have to go outside [away from the village]."* (FGD-Men, NWM village)

In NWM village, women stated (I) that to migrate with the whole family to other locations for longer periods was necessary for them to earn some money. In IWM villages, participants stated that migration had reduced drastically after plantation of fruit crops.

> *"Migration has decreased. Due to wadi, one man is completely engaged. It decreased [migration] very much. When wadi is planted, we cannot go outside."* (FGD-Men, IWM village)

In study II, participants reported that the number of households with seasonal migration was significantly lower in IWMV (86/142; 61%) compared to NWMV (104/144; 72%) (OR = 0.59, 95% CI 0.36-0.97; $p = 0.036$).

The professional stakeholders viewed (IV) that seasonal migration affected tribal people with respect to education of children, addiction to alcohol and many health problems. Addiction to alcohol was perceived to become severe when men migrated without their families.

> *"The government provides education facilities [to tribal people] through various schemes, but the economic condition of the people is not good.….Migration affects the*

attendance [of the student] in school…. from December to January 50% of the students are out of the village [in general in Palghar-Thane district]." (FGD, Teachers)

The professional stakeholders further perceived (IV) that migration from IWM villages had reduced due to the generation of employment in agriculture in those villages. This also reduced the extra burden of work of women and the suffering of family due to migration.

Women participants from NWM villages felt (I) that they do not receive respect at the sites they have migrated to, and have to face social disparity problems. Thus they reported feeling uncomfortable at the new sites. Unwilling migration and social disrespect were looked upon with anger by the women and it disturbed their peace of mind. Their feeling of not having basic rights, being powerless and socially underprivileged, became even stronger in these situations.

"*Live anywhere, eat anything. Who is going to take care? We have to do this as we have to fill our stomach. Do whatever job we get to earn some money.....We have to live in open places. There are too many mosquitoes there. They bite us during the whole night. We cannot have a comfortable sleep. It causes shivering fever and we do not get proper health services there, being an outsider."* (FGD-Women, NWM village)

4.2.3 Education, empowerment and utilization of healthcare services

Participants from IWM villages perceived (I) education as an important tool for advancement in life as well as for obtaining better health services, and they felt that even though they were not much educated, their children were becoming educated due to income enhancement as a result of the implementation of IWMP. They perceived that this will make a difference in the future. Education was felt to be a part of empowerment in social health whereby people gain knowledge and confidence in facing situations in day-to-day life. They also viewed that, in general, people followed educated people in society, so if some people were educated, other community members followed them, and it brought about a positive change in society.

"Now our children become educated... there is a difference due to education.....If we behave well, then other person also tries to behave well. One follows other." (FGD-Men, IWM village)

The professional stakeholders perceived (IV) that increase in water availability, along with the creation of awareness regarding health, was very important. They emphasized the role of education and awareness as very important to improve the public health situation in the tribal areas, as there is a very low level of literacy among tribal communities. The stakeholders stated that there is a tradition of early age marriages in the tribal community in Palghar-Thane district, which adversely affects both women's and children's health. According to them, tribal girls got married at the age of 15-16 years or less, which not only discontinues their education, but further creates health problems like malnutrition in children and anemia in women.

Both the men and the women participants of FGDs perceived (I) that the traditional healers, the 'Bhagat' in their area, have an important role in the health service as they are either the first or the last solution for their illness, as people have faith in them. Sometimes, the 'Bhagat' is also the person who recommends them to go to a community hospital to take modern medicine. Participants from IWM village felt that lack of awareness and low educational levels in their area implies that it will take time to change the attitudes of people towards health services.

> *"In the beginning, we take tablets, medicines. If we are not cured, then we go to Jawhar or Mokhada [towns]...at the community hospital...if not cured, then we will keep treatment of hospital and will also show to Bhagat."* (FGD-Men, NWM village)

Participants viewed (I) that income level also determines the utilization of public health services, as people have to have money and time to travel to a centralized place where healthcare facilities such as PHC and community hospital exist. Sometimes they have to buy medicines from a private medical shop, because of non-availability of particular medicines at the public hospital, which again was an extra economic burden. People from IWM villages expressed that some of them have started to go to private practitioners, which is more costly, and that they are also purchasing medicines from the private medical shop as now they can afford it.

A significantly higher number of households in IWMV utilized (II) government institutional services for antenatal, natal and postnatal care (OR 3.75, 2.57 and 4.88 respectively) compared to NMWV. Another finding was that in the past three years there were significantly lower numbers of births in IWMV (34/142; 24%) compared to NWMV (52/142; 36%) (OR = 0.55, 95% CI 0.33-0.92; p = 0.025). A significantly higher number of households from NWMV (19/144; 13%) preferred to go to a traditional healer (*bhagat*) to seek healthcare services for common illnesses compared to IWMV (9/142; 6%) (OR = 2.44, 95% CI 1.08-5.50; p = 0.031).

In NWM villages, women participants viewed (I) that non-availability of water resulted in men having no work to do in the village as there was no agriculture or growing of fruit crops and that this absence of work was one of the main reasons for addiction to alcohol in men. According to them, absence of work means no income, which led men to frustration and alcohol addiction. Women participants also mentioned that addiction to alcohol not only affects men's health, but also disturbs their family life and increases the incidence of intimate partner violence. Addiction to alcohol was perceived as an important health issue by both men and women in NWM villages. This was not reported in IWM villages.

> *"Earlier it [alcoholism] was more. Now it is stopped. There was no work here. Now wadis have been grown. Crops of cashew, mangoes are grown. …."* (FGD-Men, IWM village)

According to the women participants in FGD in study I, self-groups formed due to IWMP giving them a feeling of empowerment and helped them to improve social health by helping to control antisocial behaviours like intimate partner violence after heavy alcohol consumption by men. Formation of self-help groups and participation in them were viewed by women as a positive development that had taken place due to implementation of IWMP.

The professional stakeholders perceived (IV) that to improve the public health in the study area, it is important to improve the economic condition of the tribal people. They highlighted the importance of IWMP in the improvement in agriculture as it is the main source of food and income of the tribal villagers.

"If an integrated watershed management programme is implemented effectively, water storage will be utilized for agriculture; if they get income from agriculture, their livelihood will improve, economic conditions will improve and education and health will also improve….Improvement in education and health will come only after economic development." (FGD, Teachers)

5 DICUSSION

5.1 KEY FINDINGS

The participant villagers from FGDs conducted in IWMV and NWMV, perceived that most of the health problems of tribal people in the study villages are related to water scarcity, and that integrated watershed management could directly or indirectly result in a reduction of their public health related challenges such as waterborne diseases, seasonal migration, addiction to alcohol, intimate partner violence, as well as drudgery of women. Furthermore they felt that implementation of IWMP may enhance overall empowerment of families by increasing water availability and agricultural development (I). Many of these qualitative perceptions were confirmed in a questionnaire based study in which tribal people in IWMP implemented villages reported advantages on many aspects of public health. They reported that they experienced significantly less prolonged water scarcity (OR = 0.02), had a greater number of toilets (OR = 6.95), cultivated a greater variety of crops (OR = 2.61), had lower migration (OR = 0.59), had a higher number of girls continuing education (OR = 3.04) and had better utilized modern healthcare facilities in antenatal, natal and postnatal period (OR = 3.75, 2.57, 4.88 respectively) compared to NWMV (II). The odds of fecal coliform contamination in water samples from drinking water sources were 2.3 times higher in NWMV compared to IWMV, and corresponding to this, the number of severe diarrhoeal cases per household was also higher in NWMV (42/663) compared to IWMV (18/663). Resistance of *E. coli* from water samples from NWMV was to a wider range of antibiotics compared to IWMV (III). The perceptions and experiences shared by professional stakeholders, in rural healthcare and development administration associated with the study area, suggest that implementation of IWMP in a tribal area helps to increase water availability and to improve agriculture, which has a positive influence on economy and education leading to improvement in public health (IV).

5.2 INTERRELATIONSHIP BETWEEN WATER AND HEALTH IN THE CONTEXT OF INTEGRATED WATERSHED MANAGEMENT

5.2.1 Water availability and socioeconomic development

According to the professional stakeholders, water scarcity is the result of inefficient management of water resources. Both professional stakeholders and participant villagers stated that implementation of the IWMP resulted in an increased availability of groundwater, even in water scarce summer season in IWMV. This happened because implementation of IWMP helps in recharging ground water by building water-harvesting structures, thus enhancing water sustainability (2011). The study area belongs to the Deccan Plateau of India, and a rise in the water table has been demonstrated in this region after implementation of IWMP (Garg and Wani 2013).

The perceptions of tribal villagers and also the professional stakeholders, suggest that scarcity of water is a major constraint in the socio-economic development of the villages in the study area. The perceptions of the villagers and professional stakeholders regarding the association

of scarcity of water with poor socio-economic development are consistent with other studies on the relationship between water and economic growth, which suggests that economic growth is positively associated with effective utilization of water resources (Barbier 2004, Kumar, Shah et al. 2008). The perceptions of the participant villagers indicate that socio-economic development achieved by efficient water use through integrated watershed management can result in improvement in public health. The importance of socioeconomic development in reducing population-level health disparities in the society has been mentioned in an earlier study from India (Subramanian, Smith et al. 2006).

5.2.2 Water, sanitation, hygiene and waterborne diseases

According to the perceptions of professional stakeholders, water scarcity in tribal villages affects many hygiene and sanitation practices. Due to this tribal people suffer from various water related diseases like diarrhoeal diseases. This is consistent with the findings of a study from Nigeria, which suggests that diarrhoeal diseases such as cholera, typhoid fever, salmonellosis, gastro-intestinal illnesses and dysentery were the health consequences of water scarcity (Muta'aHellandendu 2012). A study from Zimbabwe also informs that water scarcity is responsible for water-related diseases in the concerned area and its effects are more severe in resource poor settings (Nyemba, Manzungu et al. 2010).

Distance to water source and infections

In the study area, though there was no water supply system up to houses, the professional stakeholders perceived that people from IWMV had water sources closer to their houses, which helped them to maintain hygiene in households better compared to NWMV, as they could easily carry water to their households. In the summer season, when scarcity of water becomes severe, professional stakeholders perceived that there are occurrences of skin infections and gastro-intestinal disorders. A study from rural Alaska natives also suggests that in water scarce areas, the risk of skin and gastro-intestinal infections increases when there is no home-water service (Hennessy, Ritter et al. 2008).

Hand washing

It is well known that proper hand washing with soap helps in the reduction of diarrhoeal diseases (Curtis and Cairncross 2003). There was awareness in both the settings regarding the need for hand washing before meals and after defecation. This awareness about need for hand washing even in this remote tribal population could be due to the advocacy campaigns by various government and non-government agencies. This knowledge however did not translate into practice, especially regarding hand washing before meals. Higher numbers of respondents reported washing hands after defecation in both IWMV and NWMV compared to hand washing before meals. In a study from Bangladesh 88% respondents reported use of soap for washing hands after defecation compared to only 22% before meals (Rabbi and Dey 2013). Multiple factors can influence hand washing in a rural community. A study from rural India found that positive predictors for hand washing among adolescents included presence of

toilets, availability of soap and water in the household washing area, and a higher per capita income (Dobe, Mandal et al. 2013).

Use of toilets

Participants from study villages perceived that improper sanitation practice such as open air defecation in the villages was due to water scarcity. Open-air defecation is one of the important reasons for the fecal contamination of water in tribal areas (WHO 2014). The Government of India has initiated efforts to make open-defecation free villages, but these efforts have not yet had to yield the desired results (Boisson, Sosai et al. 2014). Water scarcity could be one of the reasons for tribal villagers not constructing toilets. The findings of the present study show that in IWMV about 56% of the households are using toilets compared to only 15% in NWMV. Implementation of IWMP might have facilitated the building of toilets in IWMV due to both making water available for toilets, and creating more awareness. The prime-minister of India has taken initiative and started a campaign, called 'Clean India' that will ensure that every household has a toilet by the year 2019 (WaterAid 2014). To make such campaigns successful in water scarce rural and tribal areas, there should be more focus on activities like IWMP. In India, about 25 percent of villages do not have an assured drinking water source for about four to five months in a year (Hegde 2004). Diarrhaeal diseases are also common in such villages. Thus making water available throughout the year using proper water resource management practices could be a solution for such a situation.

Disinfection of community drinking water source

Water borne diseases are of common occurrence in many tribal areas and these can be prevented by appropriate disinfection of water (Khandare, Siruguri et al. 2008). Both villagers and professional stakeholders perceived that if a drinking water source is available for the villagers throughout the year is likely to reduce the epidemics of diarrhoeal diseases in the community, as the chances of regular disinfection (chlorination) of water sources are higher if the same source is used all the time. In IWMV, water is available from water wells for a longer period of the year. The need for disinfection of water in the wells throughout the year was perceived as important by significantly more respondents in IWMV (120/145, 86%) compared to NWMV (95/144, 66%). The finding from the testing of microbiological safety of water from community water wells showed lower fecal coliform contamination in IWMV compared to NWMV. Thus, it appears that the availability of water throughout the year in common water sources such as wells is important in the control of various water borne infections, as there is more possibility that water will be disinfected by villagers. In water scarce tribal areas, IWMP can be an important tool to make safe drinking water available throughout the year.

In both IWMV and NWMV, the water in the wells showed fecal coliform contamination. In both types of villages, several households had cattle. Besides contamination from human sources, animal litter can also be a potential source of water contamination in these villages,

which may have resulted in the contamination of water in IWMV as well as in NWMV especially in the rainy season, as the area receives a high level of precipitation, and therefore surface water runoff is very high.

Contamination of water at household level

The women participants from study villages perceived that improper hygiene and sanitation practices in the villages are responsible for the contamination of community water sources. Interestingly, hygiene at the household level was not perceived by them as a possible reason for contamination of household drinking water. In the tribal villages included in the study, women were responsible for household hygiene. The results of the test for faecal coliform contamination of drinking water from household storage containers showed contamination in water in both IWMV as well as NWMV. The percentage of contamination was however lower in households in IWMV compared to NWMV. Implementation of IWMP and subsequent increased awareness regarding sanitation, hygiene and water handling during storage, might have resulted in lower fecal coliform contamination at a household level in IWMV. Earlier studies suggest that microbiological quality of drinking water declines from source to point-of-use (Wright, Gundry et al. 2004).

Antibiotic use

Water sources are prone to microbial contamination if not protected properly. Improper hygiene and sanitation practices of the inhabitants may lead to faecal coliform contamination of water sources and cause diarrhoeal diseases. Antibiotics are used to control such bacterial infections. Thus, use of antibiotics in an area is an indication of the infections or illness in a particular area. The figures of total antibiotics delivered to PHC sub-centers were higher in IWMV as compared to NWMV during the study period and even in the three previous years. An important outcome of implementation of IWMP is the socio-economic development and reduction in migration in IWMV. Besides that there might be greater awareness of health among villagers of IWMV. Thus, in the IWMV there is an increased awareness about utilizing health services which might have led to more antibiotic prescriptions than in NWMV. Furthermore, because of less economic development, people from NWMV migrate more frequently for work outside their villages than people from IWMV, thus the population staying throughout the year in IWMV is higher compared to NWMV. There are also differences in between the two settings with regards to the type of health service the tribal villagers use. The data on utilization of formal healthcare services suggest that the people from NWMV believe more in using traditional measures compared to people from IWMV. All these factors might have resulted in more delivery of antibiotics in IWMV.

Antibiotic resistance

Table 4.3 shows that *E. coli* isolates from water sources from NWMV exhibited resistance to a wider range of antibiotics compared to the *E. coli* isolates from water sources from IWMV. In NWMV, resistance was recorded to antibiotics that were not delivered there. Seasonal

migration in tribal areas was reported to be responsible for many public health issues (I). It is possible that at migration sites, tribal villagers might have been treated with the antibiotics and their gut bacteria had developed resistance to it, which might have been passed on to water sources in their home villages, after fecal contamination due to open air defecation. It is also possible that these people might have picked up resistant strains through environmental contamination from sites where tribal villagers migrated. The water sources might have been contaminated by tribal people through improper sanitation practices. In the context of this finding, it appears that an integrated watershed management policy that is helpful in reduction of migration in tribal areas might thus become also helpful in curtailing the spread of antibiotic resistance. Furthermore, it should also be remembered that water contaminated by resistant bacteria poses the risk of spreading antibiotic resistance in the environment (WHO 2013). Often, antibiotics are used in the treatment of non-bacterial infection. Such unnecessary use of antibiotics may lead to further development of antibiotic resistance. It is possible that especially at the migration working sites, such misuse might occur.

A redeeming feature of the findings of the present study is that there is high susceptibility to antibiotics in the in the study villages (Table 4.2). Many studies from India and abroad have shown high antibiotic resistance by *E. coli* isolated from water sources (Efuntoye and Apanpa 2010, Patoli, Patoli et al. 2010, Sahoo, Tamhankar et al. 2012).

5.3 INTERRELATIONSHIP BETWEEN WATER, AGRICULTURE AND HEALTH IN THE CONTEXT OF INTEGRATED WATERSHED MANAGEMENT

5.3.1 Agriculture, food and nutrition

Agriculture was the main occupation reported in both settings i.e. IWMV and NWMV. Most of the crops grown in the area were reported to be for self-consumption and not for sale. This is similar to the practice reported from the Bharmaur tribal area of Himachal Pradesh in India (Jaglan and Thakur 2006). Such practice suggests that the nutrition of tribal people mainly depends on the cropping pattern i.e. type of crops cultivated. Additionally they also eat forest produce like wild vegetables and fruit. Often, such practice does not fulfill the nutritional requirement of the tribal people, and malnutrition has been reported as a major public health concern in many tribal areas (Khandare, Siruguri et al. 2008). The study participants had similar perceptions, and this is consistent with the findings of a study from another tribal area in India, where a major proportion of food came from under-developed agriculture and it was considered to result in malnutrition, mainly in children (Rao, Rao et al. 1994). Malnutrition has been reported to be associated with under-five mortality (Jangpangi 2011). There are other studies that also suggest a link between agriculture and nutrition in resource poor settings (Chen, Chowdhury et al. 1979, Allen, Bourke et al. 1980, Gulati, Ganesh-Kumar et al. 2012). In the present study, IWMP has been reported to be influential in making available better staple food, which can further be linked to nutrition. To improve the nutrition in tribal areas, where most of the food is derived from subsistence agriculture, more efforts are needed for the improvement of agricultural practices, along with efficient use of water to overcome the problems of malnutrition or under-nutrition.

The professional stakeholders, as well as villager participants, perceived that agriculture in the area is not developed and lacked advancement. The professional stakeholders further perceived that tribal people lack adequate knowledge of cultivating different crops. However they also stated that there was an increase in water availability in IWM villages and water was used for the development of agriculture in those villages. Thus IWMP can be helpful in the improvement of nutrition by improving the agriculture in tribal areas.

In IWMV about 70% of the households were growing fruit and vegetable crops, whereas it was less than 50% in NWMV. This indicates that increased availability of water increases the variety of crops cultivated. In IWMV, about 57% of the participants perceived an increase in income from agriculture as a positive impact of IWMP. The increase in income level in IWMV can also increase the capacity of the tribal people to purchase fruit and vegetables for their own consumption. Increased net return from agriculture has been demonstrated in watershed management sites from Thailand, India and China (Wani, Dixin et al. 2012).

5.3.2 Agriculture, economy and migration

The development of agriculture is very important in settings where economy is dependent on it. Socio-economic status is one of the key determinants of health. In the study area, agricultural output determines the socio-economic status of an individual.

Seasonal migration and health

Agriculture, mainly rain-fed, is the main occupation of the majority of the tribal population in the Palghar-Thane area, which generally resulted in no work in non-rainy seasons. Other avenues of employment were scanty. This type of situation forces people from tribal areas to migrate in search of employment. A similar situation was reported in other parts of the world such as Nicargua and Ghana (Braimoh 2004, Marquette 2006, Deshingkar 2010). When ecosystem services within a watershed do not provide basic material for life or freedom of choice of work, then people have to migrate unwillingly to other places (Millenium Ecosystem Assessment 2005). In resource poor settings, migration is reported as one of the social determinants of health (Parkes, Morrison et al. 2010). Multiple physical, psychological and social health problems result from such distress migration (Carballo and Nerukar 2001, Bhugra 2004, Adanu and Johnson 2009). Poor quality of accommodation, geographical isolation, crowding, a deficiency of toilets and poor cooking facilities were identified as determinants of poor health (Bolaños, Partanen et al. 2008). In contrast, migration has also been seen as an opportunity for economic development and for reduction of poverty and inequality between urban and rural areas (Deshingkar 2010). However, tribal villagers involved in the present study did not perceive migration as an opportunity, as it was a forced migration resulting from a distressed situation.

Women participants from the study villages viewed that they are not respected at sites where they migrated. They felt that they were treated as a member of a lower class in social structure during migration, which suppressed them mentally, and they did not feel comfortable in such situations. These findings are consistent with the findings of an earlier

study, which suggest that most of the migrants perceived themselves as being under stress, and put themselves at greater risk of experiencing psychological difficulties (Kim-Godwin and Bechtel 2004).

According to the villager participants of the study, they migrate to gain some employment as a seasonal labour, and most of the time they are not provided with good accommodation by the employer. They further perceived that they suffer from malaria in those situations as they have to sleep outside in open places and there is no protection from mosquitoes. Often, they come back to their own villages after getting ill. The participants' views on transmission of communicable diseases like malaria during migration is consistent with the findings of an earlier study (Saxena and Devadethan 1998), in which it is reported that seasonal migration of labour has an impact on the spread of malaria. There could be spread of malaria from seasonal workers for a temporary period and similar results are reported from studies conducted in rural Venezuela and other locations (Caraballo and Rodriguez-Acosta 2003, Grieve 2005). A study on migration and an HIV epidemic in south west India suggests that there is an increased risk of spread of HIV infection during seasonal migration (Deering, Vickerman et al. 2008). Tribal people may even be at a greater risk of getting HIV during migration when they migrate alone, as there is illiteracy and lack of awareness regarding sexually transmitted diseases among them.

Migration and IWM in a tribal area

In IWMV, migration was significantly lower than in NWMV, probably because of the generation of gainful employment within the village due to improved agriculture resulting from implementation of integrated watershed management leading to reduction in migration and associated public health problems.

5.4 EMPOWERMENT AS A RESULT OF INTEGRATED WATERSHED MANAGEMENT

Women participants from FGDs perceived education as a domain of empowerment, which was reflected in their views about their daughters' education. In most of the rural tribal areas, women spent their productive time collecting water for household use. Collecting firewood, to use as a fuel for cooking, is another necessity in these hilly tribal areas, and this is also burdened on women. In India, about 87% of tribal families use firewood, crop residues or cow dung as a fuel for cooking (GOI 2011). The findings of the present study suggest that integrated watershed management resulted in reducing the water scarcity period. In IWMV, water was available in sources relatively close to villages, even in the water scarce summer season. Plantation alongside contour trenches helped the villagers some firewood available. Women participants perceived that this saved their time collecting water and also reduced the burden of work. A similar view was mentioned earlier stating that in an improved watershed in tribal areas, women could be empowered by imparting on them the skills and education needed for their development, and time saved from collection of water could be utilized for other income generating activities through self-help groups. In addition, women can spend

more time maintaining the household hygiene (Deshingkar 2005). Maintaining the household hygiene is again a responsibility of women in tribal areas of India (Bhasin 2007) that is directly linked to the health of all the family members. In rural tribal settings, girls usually assist their mothers in the household work and that affects their school education. The findings of this study suggest that a significantly higher number of girls could continue their school education in IWMV compared to NWMV, which might be a result of reduction in time for household work.

Time spent on activities such as 'education and awareness', 'income generating activities through self-help groups' and 'involvement in decision making processes' makes women feel empowered in IWMV. Formation of self-help groups is recommended in the common guidelines formulated for watershed development projects by the Government of India (2011a). Women participants from IWMV found self-help groups useful, as it gave them a platform to discuss their problems and find solutions. In tribal villages, unions of women gives them a voice and helps solve social issues such as intimate partner violence, particularly that resulting from alcohol addiction in men. Earlier studies support the link between alcoholism and intimate partner violence in different parts of the world (Brisibe, Ordinioha et al. 2011, Jayasuriya, Wijewardena et al. 2011) and suggest that young women are at increased risk of violence from their alcohol addicted partners. According to the women participants, the intensity of alcohol addiction varied in men depending on the socio-economic development in their village. These findings are consistent with earlier research that supports the relationship between socioeconomic development, alcohol addiction in men and resulting intimate partner violence (Pangare and D'Souza 1998, Bhasin 2007). According to the professional stakeholders' perception, alcohol addiction in men in tribal societies is a common phenomenon. They perceived that lack of education is one of the reasons for the excessive consumption of alcohol, and that affects overall family health. This perception is supported by the findings of another study from rural India, which states that men from scheduled tribes who have no formal education consume excessive alcohol (Neufeld, Peters et al. 2005).

Women empowerment is a key rights issue. Reduction in drudgery and empowerment through education and awareness as a result of IWM enables women to claim their rights towards improved psychological, social and physical health. Integrated watershed management thus might be a pathway in the improvement of public health through socio-economic development of tribal communities.

Water scarcity influencing health of women

Views were put forth in FGDs that, besides household work at home, women are burdened with the work of collection of water from water sources, and they have to spend most of their time doing it. This becomes hard work for them and it affects their health. It is documented that in rural tribal areas of India, in water scarce regions, women have to undergo this drudgery (Bhasin 2007).

From the past experiences, the professional stakeholders stated that they observed a high percentage of anemic tribal women in health camps, especially in those villages where the water scarcity situation is worst. In India, about 68% of tribal women are anemic and 80% of tribal households do not have their drinking water source within their premises (GOI 2011). In India, higher maternal mortality and infant mortality rates are reported in tribal populations compared to the general population (GOI 2013). To increase the water availability throughout the year or at least for a larger period of the year is the main objective of the IWM. In the present study, it has been reported by the villagers in IWMV that prolonged water scarcity was lesser in their villages compared to NWMV. If water scarcity is related to women's health and anemia is one of the indicators of it, then more research is needed on how to overcome this problem in the context of water scarcity. IWM could be helpful in the improvement of the situation regarding anemia in tribal areas by making water available throughout the year, and also within or close to, tribal households.

5.5 UTILIZATION OF HEALTHCARE SERVICES

There should be effective utilization of healthcare facilities for the improvement of public health in tribal areas. This can be facilitated by educating the people and creating awareness among them about their health. The perceptions of the study participants, both villagers and professional stakeholders, suggest that many health problems of tribal people are associated with lack of education, which also increases their reliance on traditional healthcare measures. The high infant and maternal mortality among tribal population results from multiple factors such as: lack of access to healthcare, especially emergency care; illiteracy; social customs and beliefs; non-availability of qualified health care providers; and reliance on traditional healers (Arora 2005, Subramanian, Smith et al. 2006, 2010). Tribal people in many parts of the world are in need of education, which they often lack (Stephens, Nettleton et al. 2005). A study from Peru suggests that formal education imparted to women positively influences the utilization of maternal healthcare services (Elo 1992). The development programmes like IWM aim to achieve socio-economic empowerment of people leading to increased awareness about the use of formal healthcare systems. Higher institutional deliveries in IWMV compared to NWMV are one of the indicators of increased awareness about utilization of formal healthcare services among IWM villagers.

Traditions and healthcare

Traditions play an important role in the determination of health and healthcare practices in many populations of the world, and this is especially true for tribal populations (Rowse 1996). Many healthcare practices are ingrained in traditions, are still important, and add knowledge to the health science. According to professional stakeholders, in the study area, tribal people used local herbs of medicinal importance to cure many illnesses, but little importance was given to knowledge of tribal villagers. It is believed that tribal people have knowledge about herbs that are being used as traditional medicine, and there is a need for conservation of these plants and also the knowledge (Uniyal, Singh et al. 2006, Ragupathy, Steven et al. 2008). Traditional knowledge of medicinal herbs is losing its importance

because it is often entangled with superstitious practices. There should be good documentation of this knowledge, and as these herbs are a natural resource, their conservation can be done in a watershed by including them in an IWMP. However the professional stakeholders also stated that there are some traditions of tribal communities that adversely affect their health. Bathing neonates with water of ambient temperature in an open environment is an example that results in adverse effects, since it is perceived to result in pneumonia. Similar traditional newborn care practice has previously been reported from India (Verma, Shrikiran et al. 2012, Shah and Dwivedi 2013). Infant mortality is a major public health problem in the area and tribal people need to be educated about correct practices. The professional stakeholders described another tradition of marriages in early age, which they perceived to be a reason for many health problems of women and children in tribal communities. There are studies from Africa and India that support the perception of professional stakeholders, reporting the existence of early age marriages in tribal societies and associated health problems of women and children (Maharatna 2000, Nour 2006). Findings of this study are consistent with these studies and suggest that there is a need to educate the tribal people and to create awareness among them to stop early age marriages along with the empowerment of women in the society (Maharatna 2000, Nour 2006). Awareness and education about these issues was included in many IWM projects in India and could be included in IWM projects all around the world. Empowerment of women and also families was perceived as a result of IWM by the villagers in this study. Thus integrated watershed management can play a role by promoting education among the tribal people so that they would be able to differentiate between useful and harmful traditions and indigenous knowledge existing in the tribal societies. This is even more important in case of India, where traditional medicines are included by the government in the formal healthcare system by creating a separate department of AYUSH (Ayurveda, Yoga, Unani, Siddha and Homeopathy) and research on traditional medicine is also promoted through it (Dutt, Kumar et al. 2009, Patwardhan and Mashelkar 2009).

5.6 INTER-LINKAGE OF FACTORS INFLUENCING HEALTH

Integrated watershed management includes many aspects which independently and together, concurrently and successively act to influence public health. The various factors described in this study indicate that they have direct and indirect impacts on health. Many factors are dependent on other factors and have a link between them. For example, water availability helps improve agriculture, which further helps in reduce migration and health problems associated with it, thus has a positive impact on health. Improvement in agriculture also has a positive influence on health by increasing the variety of food available through cultivation of different crops, and improving the nutritional status of a population. Reduction in migration also helps to improve school attendance, thus helping in the improvement of education, which is also positively associated with health. Increased water availability itself influences several aspects of public health. Many factors influence on health either in an independent way or there may be a combined effect of many of them. The findings of the study show that in a hilly tribal setting, integrated watershed management influences public health through

various factors that are inter-linked with each other. This study indicates that management of water and agriculture through integrated watershed management influences public health positively. An exploratory representation of this complex inter-linkage in an IWMP implemented hilly tribal area is shown in figure 5.1.

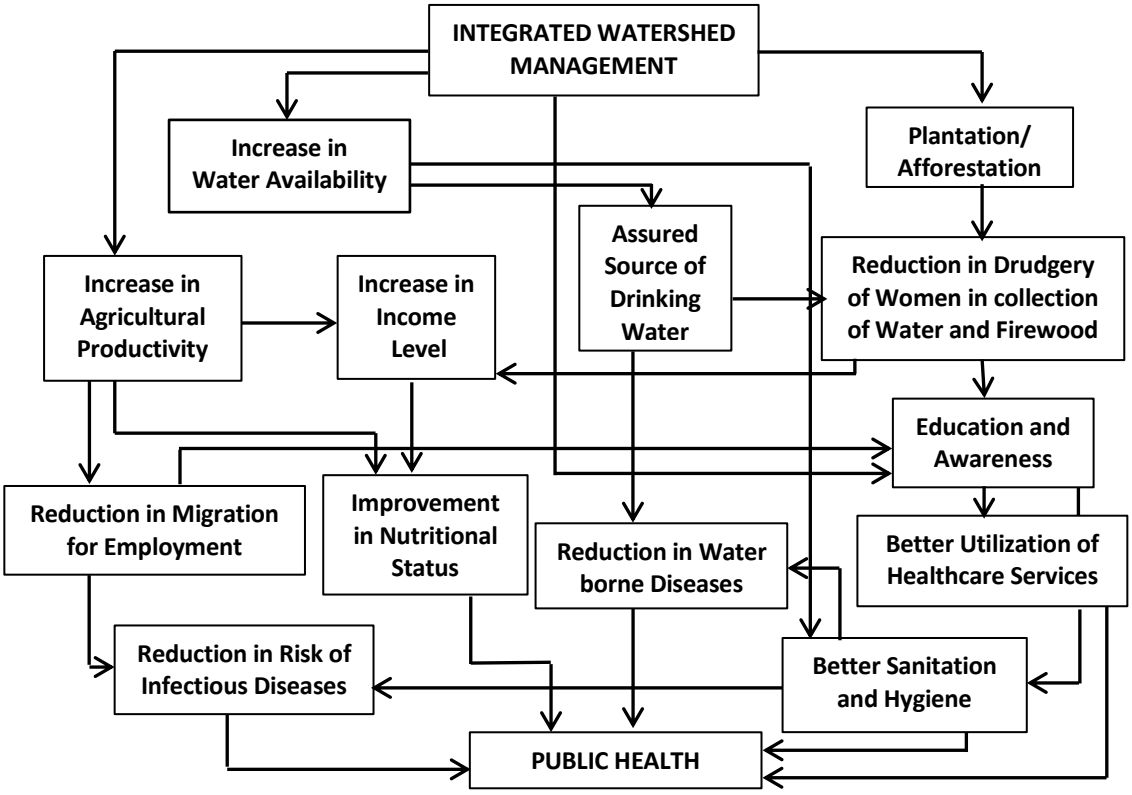


Fig. 5.1 An exploratory representation of complex inter-linkage of various factors affecting public health in an integrated watershed management programme implemented hilly tribal area

5.7 MILLENNIUM DEVELOPMENT GOALS AND INTEGRATED WATERSHED MANAGEMENT

The United Nations had taken an initiative in 2000 to set eight Millennium Development Goals (MDGs). These goals are time-bound and quantified targets addressing the basic rights of health, education, shelter and security, and have a deadline of 2015. These goals are enlisted as follows.

1. To eradicate extreme poverty and hunger
2. To achieve universal primary education
3. To promote gender equality and empowerment of women
4. To reduce child mortality
5. To improve maternal health
6. To combat HIV/AIDS, malaria, and other diseases
7. To ensure environmental sustainability
8. To develop a global partnership for development

There is an ongoing discussion about the success in the achievement of these goals. Many countries achieved the set target for certain goals well before the deadline of 2015. However there are many countries that are not even close to the target.

If we think to work on these goals at a village level, keeping in mind the findings of this study, integrated watershed management can be seen as a ray of hope to achieve these targets in near future in hilly tribal areas. The goals 4, 5 and 6 are directly related to health, and goals 1, 2, 3 and 7 have an indirect impact on health. From the findings of this thesis, one can say that many of these goals cannot be achieved in settings such as rural tribal areas of India, where development is dependent on, and is centered around, water availability, unless the issues related to water availability are solved.

In these types of settings, development of agriculture is important as this will help i) to eradicate extreme poverty and hunger by changing crop patterns and improving productivity, ii) to achieve universal primary education by increasing the enrolment in schools and continuation of education of children by reducing seasonal migration, and iii) to promote gender equality and empowerment of women by involvement of women in the decision making process by creating self-help groups. About 70% of the MDGs' target populations live in rural areas of Asia and Africa, and for most of the rural poor, agriculture is a critical component in the successful attainment of the MDGs. There is a strong link between agriculture and MDG1, which emphasizes the improvement of agriculture for achieving MDGs (Rosegrant, Ringler et al. 2006). Integrated watershed management helps to improve water availability for agriculture, thereby reducing burden of work on women, improving nutrition by developments in agriculture, and reduction in seasonal migration. Along with these, there are other linked benefits that may help to achieve the target of MDGs 4, 5 and 6. Furthermore, to achieve environmental sustainability by management of natural resources is one of the main objectives of the integrated watershed management.

For a rural tribal setting like in this study, availability of water and development of agriculture seem to be important to achieve MDGs. These goals have direct implications on health. So this study suggests a holistic approach of integrated water, health and agriculture management that is economically feasible, socially acceptable and environmentally sustainable to achieve health and well-being of tribal people.

5.8 METHODOLOGICAL CONSIDERATIONS

This study explores public health situations in two settings, one with implementation of the IWMP and other without its implementation. The complete implementation of IWMP may take from four to seven years and the period may vary according to the size and topography of the watershed. Furthermore it takes time, may be several years, to see the results of the implementation. Thus even in a "before and after" evaluation, without a control group, it is difficult to know, what are effects of the programme, and what are secular trends. It was therefore decided to assess public health aspects in two settings, one with IWMP and one

without IWMP, at the same time point. This study describes the differences in the two settings by comparing a range of aspects related to public health.

The overall study design

The use of both qualitative and quantitative approaches in this thesis enabled the exploration of the public health implications of integrated watershed management in a hilly tribal area. The perceptions of the villagers explored by the use of FGDs in Paper I was further substantiated in the quantitative Papers II and III. In Paper II, information generated from Paper I was assessed quantitatively with a questionnaire. To explore this further, a prospective study for one year was conducted, involving: a field test of physico-chemical contamination of water; and laboratory analysis of bacterial contamination of water; antibiotic susceptibility of *E. coli* isolated from water sources; and data from records of the health centers, which generated Paper III. Information generated from the first three papers was used in the individual interviews and FGDs in Paper IV, which was a qualitative study with professional stakeholders in rural healthcare and development administration.

Focus group discussions and individual interviews

FGD is a technique used to explore anticipated as well as unanticipated issues related to the topic of interest (Marshall and Rossman 2010). Paper I was based on FGDs, which was suitable for a study in a tribal context. It was more comfortable for the tribal participants to express their views in group rather than in individual interviews. For Paper I, the sampling method used to select participants was purposive, which allowed selection of participants with a range of ages and education. To conduct the FGDs, well-trained moderators were involved, which allowed smooth conduct and maximum interaction from all participants. Due to the cultural context, FGDs were conducted separately for men and women. For FGDs with women, additional female moderators were involved to make the participants feel comfortable, which in turn facilitated to generate information related to women's issues. The moderators of the FGDs were fluent in the local language and were well aware of the customs and traditions of the tribal people in the study area.

For Paper IV, both FGDs and individual interviews were conducted. For FGDs, purposive sampling helped to maintain homogeneity with respect to age and education, and variation with respect to experiences from different villages. The intention behind conducting FGDs was to generate information about experiences from professional stakeholders lower in the hierarchy who had worked in different village settings. Also for Paper IV, FGDs were conducted separately for men and women. Individual interviews were conducted with professional stakeholders higher up in the hierarchy who had a broader geographical area of responsibility. Individual interviews were conducted, with these professional stakeholders as time and availability did not allow them to participate in FGDs. These stakeholders had a variety with respect to age, experience and education that gave deeper insights in the topic of interest.

Reflexivity

In qualitative research reflexivity refers 'to the recognition that the researcher is part of the process of producing the data and their meanings, and to a conscious reflection on that process' (Green and Thorogood 2013). For this study, I was involved in the collection of the data for the qualitative studies. To the participants, I presented myself as an outsider and as a researcher. The issues discussed during the collection of data were related to the topic of the research, i.e. public health implications of integrated watershed management. Presenting myself as an outsider and as a researcher made it clear to the participants that I was not involved in the implementation of IWMP, and did not work with the implementing agency. This was believed to make participants less restricted in expressing their views.

Trustworthiness

Both techniques, FGDs and individual interviews, were used in the qualitative studies (Paper I and IV). Interactions between participants in FGDs were helpful to generate information without personal biases of the participants, while individual interviews gave deeper insights to participants' experiences and views. For Paper I, information was collected from villagers. This generated information from both actual sufferers of water scarcity, and also those who were beneficiaries of the integrated watershed management programme. For Paper IV, the participants were professional stakeholders in rural healthcare and development administration. They were involved in the implementation of policies for the tribal people. FGDs were conducted with stakeholders, who were at the bottom of the hierarchy of work, and homogeneity with respect to age and education was maintained as much as possible in the FGD groups. In these FGDs, the absence of members higher in the hierarchy allowed the members who were at the bottom of hierarchy to express their views freely. Hierarchical and educational levels and jurisdiction of work were different between interviewed individuals. In Paper IV, the same guide was used for both individual interviews and FGDs, in order to get an interaction among participants in FGDs. In Paper I and Paper IV, information was gathered from both perspectives; users as well as implementers of the policy and programmes. Thus, the triangulation of methods and data sources increased the trustworthiness of the study.

During the data analysis, cross checking of the translated data with recorded data was done to avoid misinterpretation. Both manifest and latent content analysis were used to for the analysis. The findings were interpreted in collaboration with the co-authors (Paper I and IV), who had varying backgrounds with respect to education, culture and nationality, which brought a unique perspective to the study. This enhanced the conformability of the findings. An informal member check was carried out through discussion with the study participants to check that they agreed with the interpretation of their perceptions.

Validity and reliability

According to Bogdan and Biklen, triangulation is a technique that facilitates validation of data through cross verification from two or more sources. In particular, it refers to the application and combination of several research methodologies in the study of the same phenomenon (2006). Paper I was based on FGDs that helped to generate information for Paper II and Paper III. FGDs can been used to develop surveys, as they enables information to be gathered on participants' perceptions, beliefs and values, and are well suited to address interventions that impact on a population's health (Calderon, Baker et al. 1999). Paper II confirmed most of the information generated from the FGDs in Paper I, as it agreed with various perceptions of the villagers, using a questionnaire involving close-ended questions. To improve the validity of the questionnaire, experts with experience of working in tribal areas in fields related to the topic of the study were consulted. A pilot study was conducted to check the feasibility of the study, and input from the pilot study was used to develop the questionnaire. The data collection in households was completed by study assistants who belonged to the tribal community and were well aware of the local situation, language, customs and traditions of the tribal people. This was done with the aim of generating reliable information. Interviews were conducted by a pair of study assistants. While one assistant was interviewing, the other simultaneously filled in the questionnaire based on the responses, which helped a smooth conduct of interviews. Immediately after each interview, both study assistants cross-checked and confirmed the information noted. In each village, the interviews were conducted on the same day, thus minimizing the possibility of discussion among villagers about the content of the questionnaire.

In addition to the questionnaire used for Paper II, household drinking water was tested for faecal coliform contamination by using field level rapid testing kit. This test is recommended as suitable for field studies in remote areas. It has shown a sensitivity of 94% and specificity of 97% (Gupta, Sheikh et al. 2008).

Paper III involved microbiological analysis of the community water source of the villagers. For this study, a pilot study was conducted to test the feasibility of the study. The microbiological analysis was performed in accredited laboratories using CLSI (Clinical and Laboratory Standard Institute) guidelines. The identification of *E. coli* was done with standard biochemical tests. Vitek2 instrument was used to test antibiotic susceptibility of the confirmed *E. coli* (Pérez-Vázquez, Oliver et al. 2001). Vitek2 instrument uses an Advanced Expert System (AES) that provides standardized interpretative reading of minimum inhibitory concentrations (Winstanley and Courvalin 2011). Updated AES parameters were set in the Vitek2 system to utilize default interpretation CLSI guidelines.

Strengths of the study

The main strength of the study is that several methods have been used to explore the public health implications of IWM and this has been done utilizing various perspectives and a range of different participants.

Another strength of the study is that it was conducted in a hilly tribal area where development was dependent on water availability and improvement in agriculture. Other sources of development were minimal. Therefore in such areas, a small change in water availability and agriculture can have a noticeable impact. This was reflected in the perceptions of the participants.

In the selection of villages, care was taken to maintain as much similarity as possible between the two sets of villages with respect to climate, geographical location, topography, water sources and social structures. All six selected villages were within a radius of 15 kilometers. This study included two villages for which one had to walk on a hilly terrain for about a kilometer during the rainy season, which shows the inclusion in the study of remote villages which are not easy to access, and the applicability of the findings to remote areas. For other villages access was also not very easy.

For the questionnaire based study, there was a high response rate (92%) and the use of a comprehensive questionnaire for the collection of data covered most potential public health aspects linked to the IWMP.

The test for physico-chemical contamination and laboratory analysis for bacterial contamination of water was conducted over a period of one year at monthly intervals, accessing several time points throughout the year, which is also strength of the study.

For the analysis of the qualitative data, the variety of backgrounds of the co-authors (Paper I and IV) has enriched the perspective to the analysis and has further strengthened the findings of the study.

Limitations of the study

There are some limitations of this study, which need to be considered while interpreting the findings.

The study area was remote with difficult access to the villages. It could potentially have been possible to include a higher number of villages for comparison. However, due to limitations in time, funds, and other factors determined by the feasibility study, an appropriate number of villages were included in the study.

The qualitative studies are based on the views expressed by the participants. For qualitative studies (Paper I and IV), temporary situations in the villages or surrounding area, at the time of the conduct of interviews, might have influenced the participants' views. This was out of the control of the researcher.

The influence of the temporary situations in the villages at the time of data collection might have also influenced the responses in the questionnaire study (Paper II). Also, the questionnaire based study presents the practices of households as reported by the head of the household, so actual practices might have been different and also differ among household

members. For social reasons, questions on alcohol consumption and intimate partner violence could not be included.

The data collected on antibiotics delivered and number of diarrhoeal cases relied on the records of the health centers, and maintenance of the records there was not controlled by the researcher.

We have measured water quality for one year at monthly intervals. Presence of *E. coli* was considered as an indication of bacterial contamination. The antibiotic susceptibility pattern of *E. coli* might have been different at other time points. Besides that, the susceptibility patterns might vary between different bacteria that are present in water at the same time point.

Generalizability and transferability

The goal of qualitative studies is not to generalize in the numerical sense but rather to provide a rich, contextualized understanding of some aspect of human experience through the study of particular cases (Polit and Beck 2010). In qualitative research, the term 'transferability' is used rather than generalizability. Transferability refers to the extent to which the findings can be transferred to other settings (Graneheim and Lundman 2004). Paper I explored the perceptions of villagers and Paper IV explored the perceptions of professional stakeholders in rural health and development administration. These studies generated rich information about their perceptions and experiences of the problems of water scarcity and possible impact of the integrated watershed management on public health in a hilly tribal area. The findings of these qualitative studies may be of relevance to settings with similar contexts of hilly tribal areas with a water scarce situation.

Mixed methods research involves the collection, analysis, and integration of qualitative and quantitative data within a study or coordinated series of studies (Curry, Nembhard et al. 2009, Polit and Beck 2010). In this study, a mixed method approach was used, where the quantitative studies (Paper II and Paper III) confirm the findings of the qualitative studies. In quantitative studies, the term generalizability refers to the ability to apply results of one study population to other settings and to larger populations. The findings of Paper II and Paper III may apply to similar settings such as hilly tribal areas with water scarce situations, where open dug wells are the main source of water, and the economy of the majority of people is dependent on agriculture with small landholdings. However, as many factors influence such studies in different contexts, a strict numerical generalizability seems not possible from this project. However, the whole project can be seen as similar to a 'case study' in which information is rich in a limited setting, but needs to be treated more as a qualitative study than quantitative, when it comes to transferability.

6 CONCLUSIONS

- Participants from the tribal community perceived that water scarcity was the main obstacle in their socio-economic development and consequently a reason for their various physical, mental, and social health problems. Furthermore, these perceptions indicate that infectious diseases, migration, alcohol consumption in men, intimate partner violence, and drudgery of women are the result of water scarcity. Integrated watershed management was perceived as a driver for improved public health, enhanced socioeconomic status and empowerment of families.
- In the tribal villages, implementation of an integrated watershed management programme was reported to impact positively on water availability, especially in non-rainy seasons, and it improved hygiene and sanitation by making water resources available for bathing, washing and toilet use. Furthermore, it facilitated an improvement in crop patterns, and made more fine cereals, vegetables and fruit available for consumption, improving nutritional status of the people. Improved water availability also helped to decrease migration and helped more girls to continue their school education.
- In the study villages included, bacterial contamination of water and diarrhoeal cases in the community were lower in villages in which integrated watershed management was implemented compared to villages where it had not been implemented. *E. coli* isolates from non-watershed management villages showed resistance to a wider range of antibiotics.
- Collectively, there was a high level of susceptibility (63%) to antibiotics in the analyzed *E. coli* isolates from the water sources of the hilly tribal villages. This information is valuable in the context of reports of high antibiotic resistance all over the world.
- The causes of various health problems of tribal people in hilly areas are complex and are interlinked with water availability and socio-economic factors. The perceptions and experiences shared by healthcare and development administration stakeholders suggest that implementation of IWMP in the tribal area helps in efficient use and management of water for households, as well as for agriculture purposes, and can help to boost socio-economic development and positive health outcomes in tribal areas.

7 IMPLICATIONS FOR POLICY AND RESEARCH

- Availability of water is an important aspect for public health especially in resource limited settings such as hilly tribal areas in arid tropics. Watershed management with a purely technological approach may not succeed in improving public health in such places. This study proposes that in such places, implementation of IWMP with people's participation should be considered as an important strategy to fulfill the rights of the people to have access to water and access to health.
- In this study, agriculture was perceived to be the main stimulator of socio-economic development, with a direct and indirect link to public health. Agriculture itself is known to be important for public health as most of the food is derived from it. This study recommends further research on establishing links between agricultural developments in resource limited, water scarcity settings, and recommends solutions to various problems of public health. Findings from such studies can be used help reduce the burden on health system.

- This study indicated that in the study area, many factors might have a potential effect on public health, and these factors are interlinked. To get the maximum benefit these factors must be optimized. The links may vary between settings. Every setting needs a policy that can address the various interlinked factors that have an influence on public health. It may also be worthwhile to develop measurable indices to ascertain the health impacts of various factors.

- In this study, migration for seasonal employment was perceived to be one of the important factors affecting other factors and ultimately health. In the study area, water scarcity was the main reason for migration. Therefore this study suggests that more research is needed on this aspect of IWM as it is important to know how IWM impacts on water scarcity and migration and its further links to public health.

- Though it was found that there was a high antibiotic susceptibility among the analyzed *E. coli*, there were also multidrug resistant bacterial strains found in this remote tribal area. There could potentially be a policy on continual testing of antibiotic susceptibility in remote areas to keep track of resistance development.

- Implementation of the integrated watershed management programme in rural tribal areas can potentially be recommended as a policy to improve public health of tribal people. In such areas, availability of water and improvement in agriculture can play a major role in the solution of many public health related problems. Therefore, this study suggests a policy that integrates water, health and agriculture management as a solution to various health related problems in water scarce settings such as hilly tribal areas in arid tropics of the world. An acronym "iWHAM" meaning integrated water, health and agriculture management is suggested for such a policy.

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10 APPENDICES

Appendix I

Guide for focus group discussions showing the introductory questions for Paper I

Introductory question
What is the situation of drinking water for the community in the village?
What kind of crops do you grow for home consumption and sale?
What are the hygiene and sanitary practices followed by villagers?
What is the situation of water related diseases in your village?
How do you tackle your health problems?
Do you have any idea about watershed management?
(Explanation about watershed management if needed)
How can watershed management activities influence your health?
Anything to add

Appendix II

Questionnaire for Paper II

Date: **House code:**

General Information:

Name of the Interviewee:

Age:

Sex:

Contact: Mobile: .....

Occupation: 1. Farmer 2. Farm labour 3. Shop owner 4. Service 5. Other

Information of family members:

Sr. No	Name of family member	Sex	Age	Education
		M/F		
		M/F		
		M/F		
		M/F		
		M/F		

Children's Education:

Boys:

1. Anganwadi 2. Go to school 3. Left School
4. Never been to school 5. Resident school

Girls:

1. Anganwadi 2. Go to school 3. Left School
4. Never been to school 5. Resident school

Questions:

1. How long have you (your family) been staying in this village?
   1. Since birth 2. ..... yrs.
2. Do your family members migrate for employment outside the village? Yes/No.
   If yes, Whole family/ only men/only women

Period of migration: Jan/Feb/Mar/Apr/May/June/July/Aug/Sept/Oct/Nov/Dec

3. What types of crops are grown on your land?
   i) Rice ii) Nagali (Red Millet) iii) Minor Millets
   iv)Pulses v) Vegetable vi) Fruit crops
   Which is major crop that you eat? ----------
   Which is major crop that you sell? ----------
   Other crops that you eat and sell? 1 ---------- 2 ----------
4. What do you eat in your daily diet as a major component?
   i) Rice ii) Nagali
   iii) Bhagar iv) Other:…..
5. What are the main sources of drinking water for you during various seasons?

Name of the Source	Distance from House (in Meters)	Season
i) Community Well	<200/500/1000/1500/2000	Rainy/Winter/Summer

ii) Budaki (Small well) <200/500/1000/1500/2000 Rainy/Winter/Summer

iii) Hand pump <200/500/1000/1500/2000 Rainy/Winter/Summer

iv) River <200/500/1000/1500/2000 Rainy/Winter/Summer

v) Tankers <200/500/1000/1500/2000 Rainy/Winter/Summer

vi) Springs <200/500/1000/1500/2000 Rainy/Winter/Summer

6. Do you experience any scarcity of water? Yes/No

If yes, then in which season do you experience it? Rainy/Winter/Summer

Can you say in which months?

Jan-Feb-March-Apr-May-June-Jul-Aug-Sept-Oct-Nov-Dec or last 15 days of summer

7. Do you feel change in taste of drinking water when the source changes? Yes/No

8. Do you think drinking water in household should be disinfected? Yes/No

If yes, then what do you do for disinfection of drinking water?

i) Chlorination of water (Jivan-drop)

ii) Filter it with cloth

iii) Filter and boil

iv) Filter and boil only for children

9. Where do you take bath?

i) At home ii) Near well iii) Budaki iv) River v)other.....

10. Where bathing of children (<2yrs) takes place?

i) At home ii) Near well iii) Budaki iv) River v)other.....

11. Where do you wash clothes?

i) At home ii) Near well iii) Budaki iv) River v)other.....

12. Where do you go for defecation?

i) In forest ii) Open air iii) Road side iv) Confined areas v) Toilet

Do you have toilet? Yes/No

If yes, Type of toilet- Septic tank/ Dry toilet

Do you use it? Yes/No

13. Do you wash your hands after toilet? Yes/No

If yes, then with

i) Normal Water ii) Soap iii) Ash iv) Soil

14. Do you wash your hands before meal? Yes/No

If yes, then with

i) Normal Water ii) Soap iii) Ash iv) Soil

15. Do you have animals? Yes/No

If yes, which animals? Cow/ Buffalo/ Goat/ Hen/.....

Where do you wash your animals?

i) at river ii) near well iii) in cowshed

16. Have you heard about water borne diseases and/or diseases due to water contamination? Yes/No

If yes, which diseases?

i) Diarrhoea ii) Gastro iii) Dysentery iv) Yellow fewer

v) Zadavanti (omitting and diarrhoeal symptoms) vi) Malaria

17. Are there children in your family who are underweight/malnourished? Yes/No

18. Where do you seek health service?

i) PHC ii) Private doctor iii) Traditional healer iv) Self medication

19. Do you feel that your drinking water source gets contaminated by improper sanitary practices? Yes/No

20. Do you feel chlorination of common well water is necessary to limit water borne diseases? Yes/No

If Yes, when do you feel it is necessary?

i) Throughout the year ii) Only in rainy season iii) In rainy and summer season

21. Do anyone of your family members suffered from diarrhoea/dysentery/gastro/zadavanti/etc. in past 15days? Yes/No

If yes, how many episodes of diarrhoea in a day? ……

What measures have you taken to control it?

i) Medicines from health centre ii) Traditional healer

22. In past three years, is there any birth in your family?

Yes/No

If yes, where was the baby delivered?

i) At home ii)PHC iii)other

Advice for antenatal care? i) PHC/ASHA ii) family members/traditional healer

Advice for postnatal care? i) PHC/ASHA ii) family members/traditional healer

23. Do you know about integrated watershed management? Yes/No

(Explanation of integrated watershed management in short, if needed)

Is any work of integrated watershed management in your village? Yes/No

If yes, did you participate in that? Yes/No

(Note: Information on question 21 was collected 3 times in a year)

Part B (Ten items questionnaire)

How do you think integrated watershed management influences your health/life? by

i) Increase in water availability Yes/No

ii) Increase in water use for agriculture Yes/No

iii) Increase in employment generation Yes/No

iv) Increase in income in agriculture Yes/No

v) Increase in firewood availability Yes/No

vi) Reduction in migration Yes/No

vii) Reduction in hard work of women Yes/No

viii) Reduction in diseases Yes/No

ix) Change in environment Yes/No

x) Impact on health and well-being Yes/No

Appendix III

Proforma for collection of drinking water sample from households for Paper II

Date:

House Code	Name of the household head	Sample collection Yes/No	Observation after 24 hours	Observation after 48 hours

Appendix IV

Proforma for water sample collection from community wells for Paper III

Date:

Time

Well No. 1: ----------

Well No. 2: ----------

Well No. 3: ----------

Well No. 4: ----------

Well No. 5: ----------

Well No. 6: ----------

Well No.7: ----------

Observation record sheet for water quality parameters by rapid testing kit

Well No.	pH	Turbidity	Chloride Content	Total hardness	Nitrate content	Iron content	Flouride content	Residual chlorine
1								
2								
3								
4								
5								
6								
7								

Appendix V

List of antibiotics used for susceptibility testing using the Vitek 2 AST (Antibiotic susceptibility test) cards used for Paper III

Card No.-	**AST GN 25**	**Card No.-**	**AST EXN7**
Sr. No	**Antimicrobial**	**Sr. No**	**Antimicrobial**
1	ESBL	1	Amoxicillin/ Clavulanic acid
2	Ampicillin	2	Ticarcillin
3	Ampicillin/ Sulbactum	3	Ticarcillin/ Clavulanic acid
4	Piperacillin/ Tazobactum	4	Piperacillin
5	Cefazolin	5	Cephalothin
6	Cefriaxone	6	Cefuroxime
7	Cefepime	7	Cefuroxime Axetil
8	Aztreonam	8	Cefotetan
9	Ertapenam	9	Cefpodoxime
10	Imipenam	10	Cefotaxime
11	Meropenem	11	Ceftizoxime
12	Amikacin	12	Aztreonam
13	Gentamicin	13	Meropenem
14	Tobramicin	14	Nalidixic Acid
15	Ciprofloxacin	15	Moxifloxacin
16	Moxifloxacin	16	Norfloxacin
17	Tigecycline	17	Tetracycline
18	Nitrofurantoin	18	Tigecycline
19	Trimethoprim/ Sulfamethoxazole		

ESBL—Extended spectrum beta lactamase

Appendix VI

Guide for interviews/focus group discussions showing the introductory questions, for Paper IV

Introductory question
What is the situation of availability of drinking water for the community in the tribal villages?
What kinds of crops are grown by the tribal people in the villages? (For home consumption or sale)
What is the situation regarding the hygiene and sanitary practices followed by the villagers?
How is the situation of water related and other diseases in the villages?
What are the general health problems of the villagers?
Do you have any idea about integrated watershed management? (Explanation about integrated watershed management, if needed)
How can an integrated watershed management programme influence the health of the tribal people in this area?
Anything to add